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5 October 1999

Mr. Mike Penko
Evaluation Branch
New England District
US Army Corps of Engineers
696 Virginia Rd
Concord, MA 01742-2751

Dear Mr. Penko,

Attached please find the enclosed document: Final: Raymark Phase III Ecological Risk Assessment Report: Technical Report and Appendices A-F, prepared under Task Order 9, Contract CW3396D0004. The enclosed document represents completion of Task 8 of the subject modification which has been performed by SAIC under subcontract to ENSR.

If you have any questions, please contact Chris Keyworth at ENSR (978-635-9500) or myself.

Sincerely,

Gregory A. Tracey, Ph.D.
Senior Scientist

Cc: Chris Keyworth, ENSR (1 copy)
Heather Ford. (1 unbound original and electronic file)

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Final

RAYMARK PHASE III
ECOLOGICAL RISK ASSESSMENT REPORT:
CHARACTERIZATION OF AREAS C-F,
RAYMARK SUPERFUND SITE,
STRATFORD, CONNECTICUT

TECHNICAL REPORT AND APPENDICES A-E

Prepared For:

Evaluation Branch
US Army Corps of Engineers
New England District
696 Virginia RD
Concord, MA 01742-2751

Submitted by
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Newport, RI 02840

Under Subcontract to ENSR
Task Order 9, Contract DACW-33-96-D0004
U.S. Army Corps of Engineers

5 October 1999

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1.0. EXECUTIVE SUMMARY

This report describes the results of a marine ecological risk assessment conducted for portions of the Raymark Industries, Inc. Superfund Site which is located adjacent to the lower Housatonic River in the town of Stratford, CT. On behalf of the U.S. Army Corps of Engineers (U.S. ACE), ENSR contracted Science Applications International Corporation (SAIC) to conduct a site-specific ecological investigation and to prepare an Ecological Risk Assessment (ERA) for a portion of the Raymark Site, known as Areas C-F.

The U.S. EPA's ERA framework and applicable U.S. EPA guidance were used to generate and interpret the data required to complete this risk assessment (U.S. EPA 1997, U.S. EPA 1998). The objectives of this ERA were as follows:

- Assess potential ecological risks to the aquatic environments of Areas C-F from chemical stressors associated with the Raymark Site;
- Develop information sufficient to support risk management decisions regarding site-specific remedial options; and
- Support communication to the public of the nature and extent of potential ecological risks associated with the Raymark site.

The following sections summarize the findings of each step of the assessment, including Problem Formulation, Sampling Summary, Site Characterization, Exposure and Ecological Effects Assessments, Characterization of Ecological Risks, and Risk Summary and Conclusions.

1.1. Problem Formulation

For the ERA, Problem Formulation involved determining the nature and extent of contamination of aquatic wetland, marsh, and estuarine (intertidal) media associated with Raymark sources. Specifically, this activity involved identification of contaminated media, identification of contaminants of concern (CoCs), evaluation of the spatial extent of contamination, identification of the ecological receptors potentially at risk from CoCs, and identification of appropriate assessment and measurement endpoints.

The site location is shown in Figure 1.0-1 (note: same as Figure 2.0-1). For purposes of this ERA, the study area includes the wetlands South of the Boat Club (Area C), the marshes north and south of the Boat Launch Area (Area D), the Elm Street Marsh (Area E) and Selby Pond (Area F). The environmental setting of the entire study area was once an extensive salt meadow marsh bordering the Housatonic River. All the areas have been physically altered by development. Areas C and D are directly located on the Housatonic River, and large amounts of fill have been disposed

of in the wetlands to create the Housatonic Boat Club (Area C) and the Beacon Point Boat Launch Area (Area D). Area E was presumably part of a larger meadow marsh with a historical connection between Area E and the Housatonic River. Although similarly isolated, Area F has a more natural tidal marsh community dominated by *Spartina alterniflora* and *S. patens* with a hydrologic connection with Ferry Creek.

1.2. Receptors of Concern

Some 53 species of fish and 11 invertebrate species may be expected to use the Housatonic River near Areas C, and D for spawning, adult forage, or as a nursery ground for juveniles. Recreational species includes Atlantic menhaden, black sea bass, bluefish, four species of flounder, American eel, striped bass, white perch, and blue crab. An important commercial larval bed for eastern oyster cultivation in the Housatonic River is present near the mouth of Ferry Creek. The American eel are caught in Area F.

These ecological receptors are exposed to contaminants through several routes. Aquatic organisms can take up toxicants directly from contact with water or sediments. Terrestrial organisms can also take up contaminants from direct contact with contaminated soil in both aquatic and terrestrial systems. Animals can ingest contaminants with surface water, soil, or food.

1.3. Sampling Summary

Sampling was needed to acquire updated chemistry and toxicity data for surficial sediments in the area adjacent to the site, and to gather biological data to assess the potential impact to receptors. A target analyte list was developed in recognition of a number of potential chemical stressors associated with past disposal practices and includes both metals (arsenic, nickel, zinc, copper, cadmium, chromium, lead, and mercury) and organic compounds (PAHs, PCBs, organochlorine pesticides (OCPs)) and dioxins.

A total of 16 stations for the four areas were selected. The stations were selected to confirm previous results of high concentrations of contaminants, to fill data gaps from prior studies and to characterize gradients in contaminant concentrations. Reference data from the Great Meadow station GM-08 was utilized from a prior study. This area is approximately 5 km south of Raymark study area, and does not have a direct hydrographic connection with the Housatonic River system. The stations were sampled for sediment organic and inorganic chemical analysis, porewater analysis, and toxicity studies. Natural populations of ribbed mussels were also collected at a selected subset of stations to allow characterization of contaminant bioaccumulation and trophic transfer effects. Fish samples were planned but were unavailable.

1.4. Exposure Assessment

Exposure Assessments included quantification or estimation of the concentrations of CoCs in environmental media in the exposure pathways from contaminant sources to ecological receptors. Several exposure pathways, which allow contaminant sources associated with historic activities at Raymark to impact biota, were identified. These include contaminant exposure to and bioaccumulation from water, sediments, and porewater through partitioning across organism cell membranes, incidental contact, ingestion of sediments by deposit-feeding invertebrates, and/or consumption of contaminated prey.

1.5. Ecological Effects Assessment

The Ecological Effects Assessment involved a combination of exercises to predict the occurrence of adverse ecological impact. Ecological effects were quantified by determining the relationships between exposure patterns and resulting responses of ecological systems, as determined from the measurement endpoints identified during Problem Formulation. Site-specific evaluations of toxicity were conducted for bulk surface sediments using amphipod mortality tests. Finally, food web modeling was performed to predict effects to aquatic mammal (raccoon) avian predators (black-crowned night heron).

1.6. Risk Characterization

Risk characterization is an integration of the results of the Exposure and Ecological Effects Assessments. A weight of evidence approach was utilized in this ERA, which involved analysis of contaminant concentrations *versus* observations of adverse effects, analysis of contaminant bioaccumulation, comparisons of toxicity evaluations with observed ecological effects, comparisons of exposure point concentrations with established standards and criteria for offshore media, comparisons of exposure point concentrations with published toxicity information and qualitative comparisons of apparent adverse impacts with conditions at reference stations. The results of these analyses were summarized together with information obtained during each study to characterize potential ecological risks associated with the Raymark study areas.

Risk summary Table 1.6-1 presents summary rankings for chemical exposure (Exposure Ranking) and biological effects (Effects Ranking). The application of the ranking criteria results in four tiers of adverse exposure or effects probability; baseline ("-") , low ("+"), intermediate ("++") and high ("+++") based on the evaluation described above. This provides a comparable and consistent approach across various weights of evidence so as to minimize the chance that a particular endpoint would transfer undue weight in the final synthesis of potential risks.

1.6.1. Exposure-Based Weight of Evidence

Exposure-based weights of evidence include assessment of chemical exposure in bedded sediment and organism tissues (bioconcentration).

Bedded Sediment Exposure. Chemical concentrations of CoCs measured in sediments and porewater are compared against benchmarks to predict potential adverse effects on target species from exposure to contaminants in surface sediments. Several stations have contaminant concentrations which exceed sediment and water benchmarks to an extent suggesting intermediate to high chemical exposure (Table 1.6-1). These exceedences were primarily due to PCBs and PAHs in sediment. Exceedences of more conservative criteria continued to occur for copper and zinc throughout the study area, including the reference station. The weight of evidence for indicators of chemical exposure in bedded sediments suggest a high probability of adverse exposure exists for Station D-3, intermediate exposure for five stations (D-5, E-1, E-2, E-3, F-2, F-3) and the reference location. Low or baseline exposure was observed throughout the remainder of the study area.

Bioconcentration. Bioconcentration of CoCs in site receptors was assessed by calculation of a ratio of the contaminant residue found in a receptor organism at the site to that found at the reference location. The metric is intended to predict which CoCs and receptors are chemically enriched at the site relative to regional background conditions. Hence, it is principally an indicator of chemical exposure but does not predict effects. Stations were ranked according to overall exposure and these rankings are presented in Table 1.6-1. Low exposures ("L") were apparent in Area C stations. Four stations in Area D (D-1, D-2, D-4, and D-6) also had overall low exposures to CoCs, as well as Station E-4. High chemical exposures ("H") were apparent for two stations in the Raymark study area, Station D-3 and D-5. All other stations had intermediate ("I") exposures for CoCs.

1.6.2. Effects-Based Weight of Evidence Summary

Sediment Toxicity. In this ERA, the sediment bioassays with the amphipod, *Ampelisca* were used to assess possible impacts from in-place sediments. Laboratory toxicity results generally indicated some degree of sediment toxicity to amphipods throughout the Raymark study site. The overall station-specific laboratory toxicity rankings are summarized in Table 1.6-1. High toxicity was observed at two stations (C-3 and D-6), while intermediate toxicity occurred at six stations (C-1, C-2, D-2, D-3, E-4, and F-1). Eight stations (D-1, D-4, D-5, E-1, E-2, E-3, F-3) had low toxicity to amphipods (including the reference), and one remaining station was non-toxic to amphipods (F-2). As noted in Section 4, exposure response relationships explaining the observed toxicity were not readily evident.

Tissue Residue Effects. Possible impacts of CoC residues on target species were assessed separately through Tissue Screening Concentration (TSC) and Critical

Body Residue (CBR) Hazard Quotients. A summary of these tissue residue-based effects results is presented in Table 1.6-1. The tissue residue effects rankings were baseline for all stations.

Trophic Transfer Effects. Trophic transfer effects parameters, summarized in Table 1.6-1 include avian and mammalian predator effects. The food web modeling for avian and mammalian aquatic predators assumed that Black-crowned night herons and raccoons were feeding maximally on the most contaminated of prey items available at a given station. Despite the conservative assumptions employed, none of the stations had a ranking greater than low effects. Low effects were observed at stations D-5, E-1, F-2, F-3 and reference due to trophic transfer in the avian predator of Total PCBs and DDD, Total PCBs and mercury, chromium, lead, zinc, and DDD, zinc, DDD, and DDE, and chromium, mercury, and zinc, respectively.

Ecological Effects Ranking. Overall effects to biological receptors from CoCs are summarized in Table 1.6-1. None of the stations had a baseline (B) effect rankings. Seven stations in the Raymark study area had a low ("L") effect ranking (Station D-1, D-4, D-5, E-1, E-2, E-3, and F-3). Overall high ("H") effects were observed at Stations C-3 and D-6. The eight remaining stations had overall intermediate ("I") effects.

1.6.3. Synthesis of Exposure and Effects Weights of Evidence

Discussion of each of the weights of evidence and applicable exposure-response relationships has been presented in the previous sections. The focus of this section is to elucidate concordance among exposure-based and effects-based weights of evidence, in order to characterize overall potential risk for the Raymark study area.

High Risk Probability Stations. In the present investigation, only Station D-3 is categorized as a high risk station, given a high exposure and an intermediate effects rankings. In addition, some support for exposure-response relationships were observed given that toxicity was observed and PCB concentrations in sediment were well above ER-M thresholds.

Intermediate Risk Probability Stations. Stations which the WoE demonstrate intermediate risks include Stations C-1, C-2, C-3, D-2, D-5, D-6, E-1 to E-4, F-1 to F-3, and the reference. Multiple exposure- or effects-based weights of evidence were observed in the data, resulting in an intermediate Exposure and/or Effects rankings. However, quantitative exposure-response relationships were found to be lacking.

Low Risk Probability Stations. A low risk probability was indicated for the remaining Raymark stations (D-1 and D-4). Minimal impacts are suggested by the majority of exposure and effects-based weights of evidence, and no exposure response relationships were evident.

Baseline Risk Probability Stations. Baseline risk was not assigned for any of the Raymark stations.

1.6.4. Uncertainty in Risk Estimation

The conclusions drawn in this assessment are based on a database of sediment chemistry, tissue residues and toxicity evaluations, with broad spatial coverage. The presentation of the data provides multiple weights of evidence for assessment of impacts in the Raymark areas, hence there would appear a high probability of accurately concluding the occurrence of potential risk where indicated. The present study was conducted under a comprehensive Work/Quality Assurance Plan, and data validation has been performed and found to meet the study requirements. Potential errors in the study design and protocols were minimized through peer review and evaluation. Data collection activities were reasonably complete. Thus, it is concluded that the overall uncertainty with regard to the accuracy of potential risk estimations has been satisfactorily minimized.

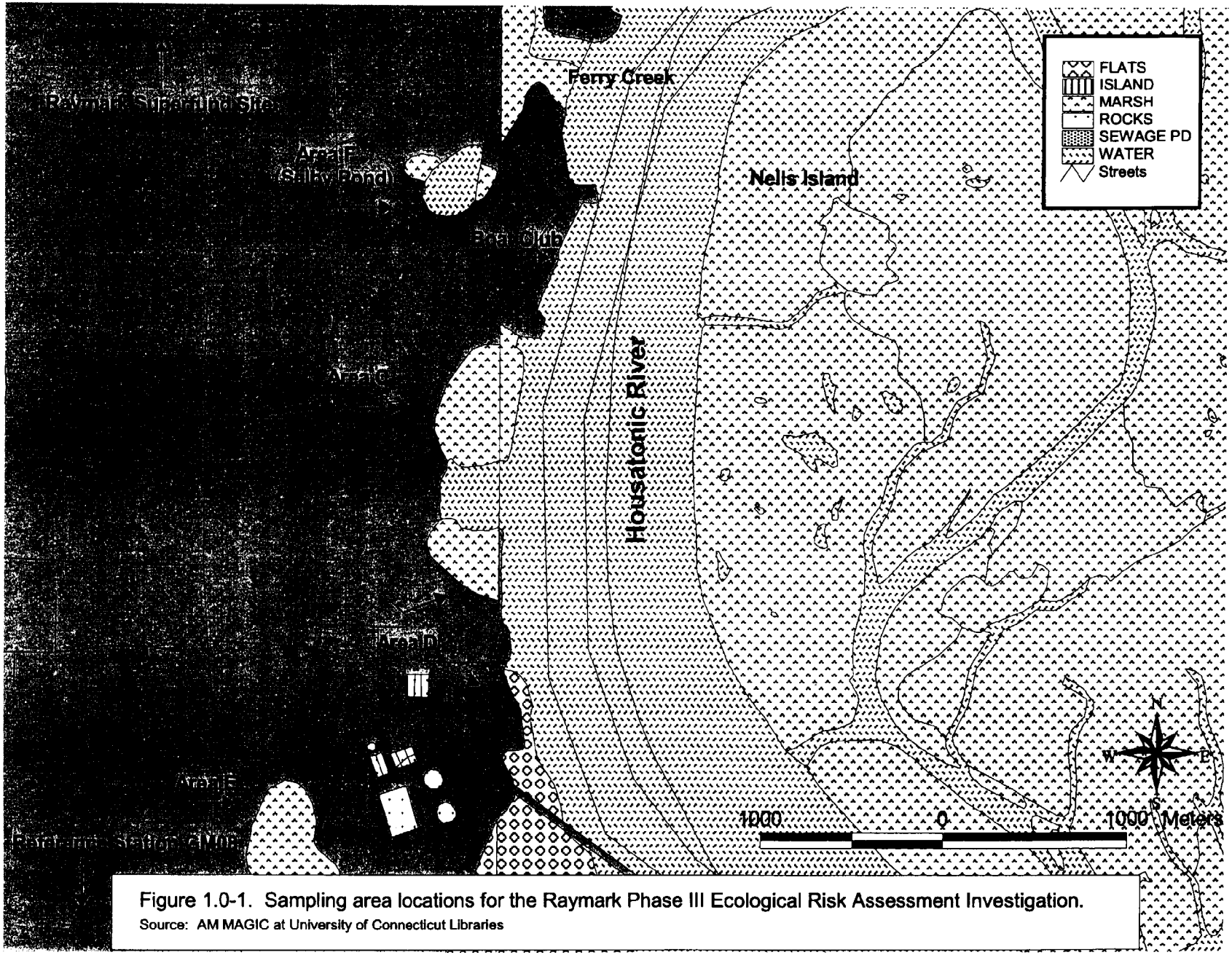


Figure 1.0-1. Sampling area locations for the Raymark Phase III Ecological Risk Assessment Investigation.

Source: AM MAGIC at University of Connecticut Libraries

Table 1.6-1. Overall Summary of Exposure and Effects-based Weights of Evidence and Characterization of for the Raymark Phase III Ecological Risk Assessment Investigation.

WEIGHT OF EVIDENCE SUMMARY								
	CHEMICAL EXPOSURE			BIOLOGICAL EFFECTS				RISK PROBABILITY
Station	Bedded Sediment[1]	Bioconcentration[2]	Ranking[6]	Sediment Toxicity[3]	Tissue Residue Effects[4]	Trophic Transfer Effects[5]	Ranking[6]	Ranking[7]
C-1	-	+	L	++	-	-	I	Intermediate
C-2	-	+	L	++	-	-	I	Intermediate
C-3	+	+	L	+++	-	-	H	Intermediate
D-1	-	+	L	+	-	-	L	Low
D-2	-	+	L	++	-	-	I	Intermediate
D-3	+++	+	H	++	-	-	I	High
D-4	-	+	L	+	-	-	L	Low
D-5	++	+++	H	+	-	+	L	Intermediate
D-6	-	+	L	+++	-	-	H	Intermediate
E-1	++	++	I	+	+	+	L	Intermediate
E-2	++	+	I	+	-	-	L	Intermediate
E-3	++	++	I	+	-	-	L	Intermediate
E-4	+	+	L	++	-	-	I	Intermediate
F-1	+	++	I	++	-	-	I	Intermediate
F-2	++	++	I	-	++	+	I	Intermediate
F-3	++	++	I	+	+	+	L	Intermediate
Reference	++		I	+	++	+	I	Intermediate

1 - Bedded Sediment Exposure Ranking based on sediment Hazard Quotients (HQs), SEM:AVS, and porewater HQs; see Table 6.1-5.

2 - Bioconcentration Ranking based on Tissue Concentration Ratios for ribbed mussels; see Table 6.2-1.

3 - Sediment Toxicity Risk Ranking based on sediment toxicity tests: see Table 5.2-1.

4 - Tissue-based Risk Ranking: Based on risks of CoCs in tissues to aquatic receptors; See Table 6.2-6.

5 - Trophic Transfer Effects Ranking: Based on results of avian and mammalian predator exposures; see Table 6.3-4.

6 - Exposure/Effects (E/E) Ranking: B = Baseline Risk; L = Low Risk Probability; I = Intermediate Risk Probability; H = High Risk Probability. Rankings for stations are equal to the maximum of individual WoE ranking.

7 - Overall Risk Ranking:

Baseline = Baseline (B) ranking for E/E WoE summaries;

Low = No greater than Low (L) ranking for E/E WoE summaries, or Intermediate (I) ranking for one WoE summary and no greater than Low (L) ranking for the other WoE summary;

Intermediate = No greater than Intermediate (I) ranking for E/E WoE summaries, or High (H) ranking for one WoE and Low (L) ranking for the other WoE summary; and

High = High (H) ranking for both WoE summaries or High (H) ranking for one WoE and Intermediate (I) for the other WoE summary.

2.0. INTRODUCTION

This report describes the results of a marine ecological risk assessment conducted for portions of the Raymark Industries, Inc. Superfund Site which is located adjacent to the lower Housatonic River in the town of Stratford, CT. The site location is shown in Figure 2.0-1. Raymark site facts pertinent to need for the ERA investigation include:

- The Raymark Industries, Inc. (1919-1989) site encompasses a 34 acre industrial property located at 75 East Main Street in Stratford, Connecticut where the manufacturing of brakes, clutch parts, and other friction products took place;
- Raymark disposed of its waste as fill at 75 East Main Street as well as 46 residential properties, numerous commercial and municipal properties, and several wetland areas in close proximity to the Housatonic River;
- Prior onshore investigations indicated that elevated concentrations of heavy metals, asbestos, dioxins, PCBs, semi-VOCs, and VOCs were present in surficial soil; and
- Screening level (Phase I) and baseline (Phase II) risk assessments conducted for Ferry Creek (Areas A-B) found unacceptable risk (NOAA, 1998).

The Raymark site must comply with requirements specified under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the National Contingency Plan (NCP), and Connecticut State Statutes. The Federal regulations mandate assessment of the risk of hazardous waste disposal sites on human health and the environment, and identification of appropriate cleanup levels. On behalf of the U.S. Army Corps of Engineers (U.S. ACE), ENSR contracted Science Applications International Corporation (SAIC) to conduct a site-specific ecological investigation and to prepare an Ecological Risk Assessment (ERA) for a portion of the Raymark Site, known as Areas C-F. The purpose of this report is to communicate the results of the assessment of potential ecological risks to habitats and biota posed by the contaminants associated with the Raymark site.

2.1. Background

The ERA described in this report has been prepared following the Work Plan for Ecological Risk Characterization of Areas C-F, Raymark Superfund Site, Ferry Creek, Stratford, CT (SAIC, 1999a), referred to herein as the "Work Plan". This assessment focuses on the ecological impacts of Raymark-related contaminants on wetland, intertidal, marsh and freshwater habitats of the Raymark Site. This assessment does not consider potential human health risks associated with the site. Furthermore, this assessment only reflects currently existing conditions and levels of activity at the site,

and does not address altered risks under potential future use scenarios involving fundamentally different conditions or activities at the site.

The Work Plan provides a description of the analytical methodologies utilized to conduct the ERA. The scope of this report is to present the results of the ERA and includes an overview of the sampling and analysis activities conducted in support of the ERA.

2.2. Report Organization

This ERA report follows the organization suggested in Eco Update (U.S. EPA, 1991a) with appropriate elements from U.S. EPA (1997a, 1998a), and EPA Region I Supplemental Risk Assessment Guidance for the Superfund Program (U.S. EPA, 1989a) and Risk Assessment Guidance for Superfund, Volume II Environmental Evaluation Manual (U.S. EPA, 1989b). These guidance documents recommend a "weight of evidence" approach to assess potential ecological risks. The approach should be based on evaluation of contaminant analytical data relative to environmental benchmarks, direct field observations, selected field and laboratory studies from the scientific literature, potential for bioaccumulation of chemicals and food web exposure modeling. Evaluation of potential risks is based on the preponderance of data; locations where a greater number of endpoints suggest adverse exposure and/or effects are presumed to indicate a greater probability of adverse risk. No preferential priority or weight is given to any particular indicator.

To assure that the required activities were conducted to meet these objectives, the ERA was conducted following general U.S. EPA guidance (U.S. EPA, 1989c, U.S. EPA, 1992a), and input provided by U.S. EPA Region I, the State of Connecticut, and Natural Resource Trustees, representatives of which jointly constitute the Raymark Ecorisk Advisory Group.

The elements of this ERA report include:

- Problem Formulation. This involved determining the nature and extent of contamination of aquatic wetland, marsh and estuarine (intertidal) associated with Raymark sources. Specifically, this activity involved identification of contaminated media, identification of contaminants of concern (CoCs), evaluation of the spatial extent of contamination, identification of the ecological receptors potentially at risk from CoCs, and identification of appropriate assessment and measurement endpoints. The information generated during the Problem Formulation was integrated into a conceptual model which identified the possible exposure scenarios and mechanisms of ecological impact associated with the CoCs. This evaluation addresses only current conditions and levels of activity at the site, and does not address potential future use scenarios involving

fundamentally different conditions or activities at the site.

- Exposure and Ecological Effects Assessments. These assessments included collection of information to quantify chemical exposures and observed or predicted ecological effects resulting from exposure. The Exposure Assessment involved quantification or estimation of the concentrations of CoCs in environmental media in the exposure pathways from source to ecological receptors. The Ecological Effects Assessment involved a combination of toxicological literature review, *in situ* characterization of receptor species, toxicity evaluations of exposure media, and modeling exercises to predict the occurrence of adverse ecological impact. Site-specific Exposure and Ecological Effects Assessment activities were determined based on the conceptual model developed during Problem Formulation.

- Characterization of Potential Ecological Risks. Risk characterization is an integration of the results of the Exposure and Ecological Effects Assessments. This represents a weight of evidence approach involving analysis of CoC concentrations versus observations of adverse effects, analysis of CoC bioaccumulation, comparisons of toxicity evaluations with observed ecological effects, comparisons of exposure point concentrations with established standards and criteria for offshore media, comparisons of exposure point concentrations with published information regarding the toxicity of CoCs, and qualitative comparisons of apparent adverse impacts with conditions at reference stations. The results of these analyses are summarized together with information obtained during each study to characterize potential ecological risks associated with Raymark.

- Communication of Study Results. Communication of the study objectives, methods, and findings of the ERA is provided in a format which supports informed risk management decisions for the site. Results of weights of evidence are assembled into a summary risk table in order to further communicate potential risks in support of risk management decisions.

Based on these guidelines, this ERA presents background information integrated with contemporary data to develop the Problem Formulation (Section 3); Exposure Assessment (Section 4); Ecological Effects Assessments (Section 5); Risk Characterization (Section 6); Summary and Conclusions (Section 7); References (Section 8); and Appendices, including raw data for Chemistry Exposure Assessments (Appendix A); Effects Assessments (Appendix B); QA/QC and Data Validation Summary Information (Appendix C); and Ecological Risk Calculations (Appendix D).

2.3. Purpose, Scope, and Objectives

The purpose of this report is to describe information collected for evaluation of potential risks from contaminants associated with Raymark to ecological receptors at the site. The U.S. EPA's ERA Framework (1992a) and applicable EPA Region I guidance were used to generate and interpret the data required to complete this risk assessment. The objectives of this ERA are as follows:

- Assess potential ecological risks to the aquatic environments of Areas C-F from chemical stressors associated with the Raymark Site;
- Develop information sufficient to support risk management decisions regarding site-specific remedial options; and
- Support communication to the public of the nature and extent of potential ecological risks associated with the Raymark site.

This ERA builds upon and incorporates findings of previous studies at Raymark, and specifically addresses three data gaps remaining from these earlier studies. These data gaps are as follows:

- Need to conduct studies on organic and metal contaminants in sediment and porewater in conjunction with toxicity studies to assess the potential toxic effect of contaminated sediments on the biota;
- Need to conduct contaminant studies of receptors to assess the potential impact of contaminated sediments on individual species and the benthic community in the Raymark Study Area;
- Need for trophic transfer modeling to assess the pathways of contaminant movement up the food chain to semi-aquatic mammals and aquatic birds.

The following sections present and discuss the data requirements and data products of the ERA, including Problem Formulation, Exposure and Ecological Effects Assessments, and Characterization of Ecological Risks.

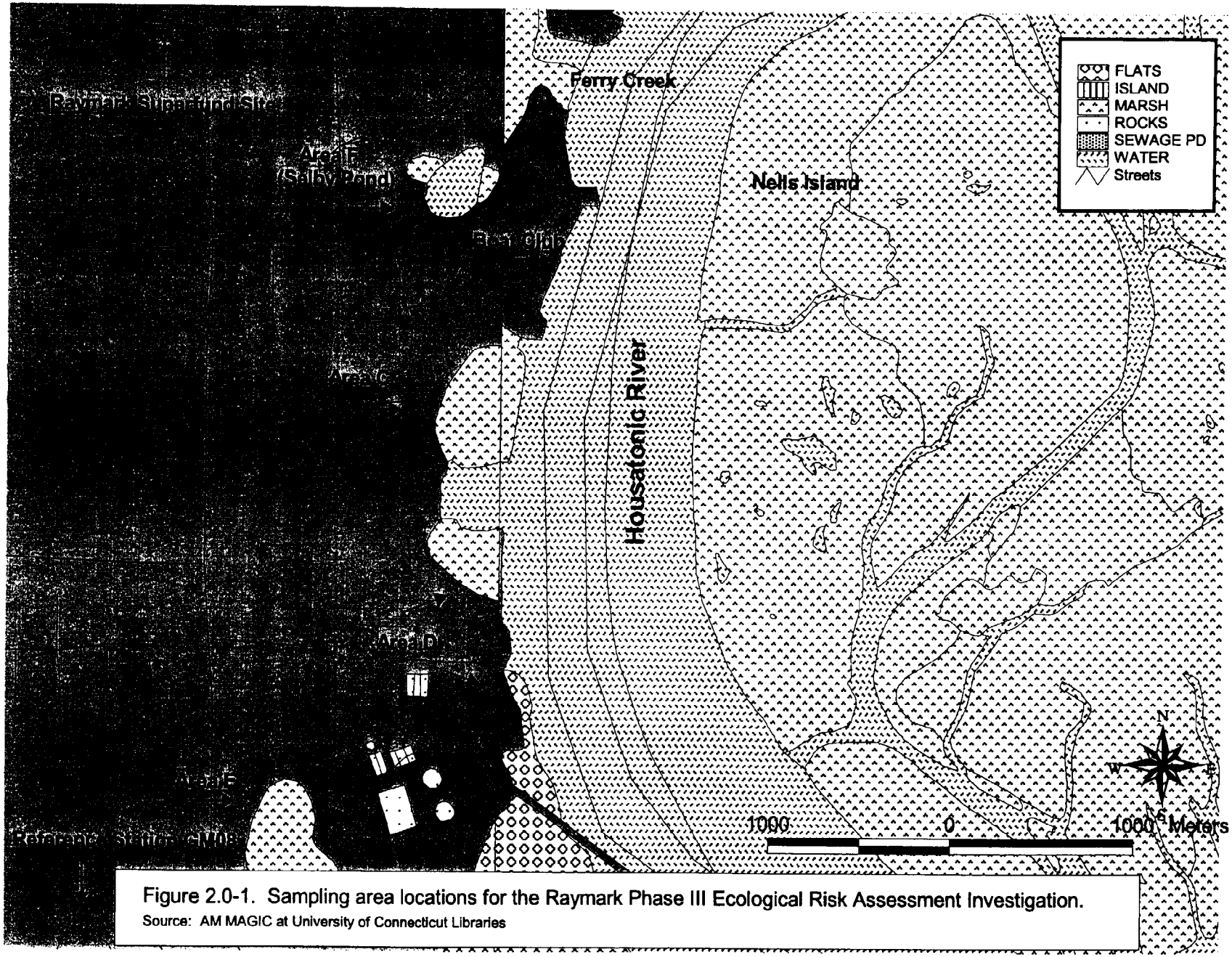


Figure 2.0-1. Sampling area locations for the Raymark Phase III Ecological Risk Assessment Investigation.

Source: AM MAGIC at University of Connecticut Libraries

3.0. PROBLEM FORMULATION

Five principal activities have been conducted in support of the Problem Formulation component for the Raymark study area ERA:

- Characterization of the site by determination of the nature and extent of contamination of aquatic media associated with Raymark study area;
- Determination of appropriate measurement endpoints;
- Identification of Contaminants of Concern (CoCs);
- Identification of the ecological receptors potentially at risk from site-related CoCs; and
- Development of a site-specific conceptual model of potential aquatic ecological risks associated with the Raymark study area.

A summary of sampling and analysis activities related to the ERA effort is also provided (Section 3.6).

3.1. Site Characterization

The primary objectives of the site characterization are to identify the types and spatial extent of habitats that are present in the aquatic environment affected by Raymark activities, identify the species and biological communities that may be exposed to site-related contaminants, and identify contaminants that may pose a threat to these habitats and species. In Section 3.1.1, the general characteristics and background of the study area are described. Section 3.1.2 discusses the habitats and potentially exposed receptors groups within the Raymark C-F study areas.

3.1.1. Study Area Characteristics

For purposes of this ERA, the study area includes the wetlands South of the Boat Club (Area C), the marshes north and south of the Boat Launch Area (Area D), the Elm Street Marsh (Area E) and Selby Pond (Area F). The environmental setting of the entire study area was once an extensive salt meadow marsh bordering the Housatonic River. All the areas have been physically altered by development. Areas C and D are directly located on the Housatonic River, and large amounts of fill have been disposed of in the wetlands to create the Housatonic Boat Club (Area C) and the Beacon Point Boat Launch Area (Area D).

In Area C, fill is seen around the upland boundary of the marsh and Phragmites is a minor component of the marsh community. The marsh is dominated by *Spartina*

alterniflora, as may be expected under natural conditions in a low marsh. Area D is similar to area C, except that filling along much of the upland boundary of the marsh is not as apparent, a large parking lot divides the marsh into two sections, and a drainage channel from the Stratford publicly-owned treatment works (POTW) runs through the Area D marsh. The upland vegetation in Areas C and D has been displaced by roads, parking lots, and buildings.

Area E was presumably part of a larger meadow marsh. The historical connection between Area E and the Housatonic River is not clear, nut it may have been through a tidal creek flowing from Area D. Most of Area E marshland is a *Phragmites* monoculture. A 600-foot culvert forms the hydrologic connection between Areas E and D, providing some tidal exchange. Although similarly isolated, Area F has a more natural tidal marsh community dominated by *Spartina alterniflora* and *S. patens*. This is most likely due to a hydrologic connection with Ferry Creek that allows sufficient tidal flow to maintain this community. Steep banks along much of the upland boundary indicate probable fill locations around Area F. The upland vegetation consists of mowed grasses and small wood lots in Area F.

3.1.2. Habitats and Potentially Exposed Receptor Groups

Some 53 species of fish and 11 invertebrate species may be expected to use the Housatonic River near Areas B, C, and D for spawning, adult forage, or as a nursery ground for juveniles (NOAA, 1998). Recreational species includes Atlantic menhaden, black sea bass, bluefish, four species of flounder, American eel, striped bass, white perch, and blue crab. The American eel and the eastern oyster are caught commercially. An important commercial larval bed for eastern oyster cultivation in the Housatonic River is present near the mouth of Ferry Creek.

Ecological receptors are exposed to contaminates through several routes. Aquatic organisms can take up toxicants directly from contact with water or sediments. Terrestrial organisms can also take up contaminants from direct contact with contaminated soil in both aquatic and terrestrial systems. Animals can ingest contaminants with surface water, soil, or food. Inhalation and uptake through foliage are also potential routes of exposure for terrestrial life, but they were not considered in the ecological risk assessment, which focused on aquatic pathways and receptors (NOAA, 1998).

3.2. Assessment and Measurement Endpoints

A target analyte list was developed in response to the regulatory requirements of the Remedial Investigation/Feasibility Study (RI/FS) for the Raymark Superfund Site, and through recognition of a number of potential chemical stressors associated with past disposal practices (Table 3.2-1). The list was based on those chemical contaminants detected during previous offshore and on-shore investigations (*e.g.*,

TetraTech, 1998), and includes both metals (arsenic, nickel, zinc, copper, cadmium, chromium, lead, and mercury) and organic compounds (PAHs, PCBs, organochlorine pesticides (OCPs), dioxins). The list reflects current understanding of those chemicals which are both of toxicological importance and persistent in aquatic systems. It encompasses selected potentially toxic chemicals which may serve as indicators of human activity (although for different uses) and whose discharge into the environment has been enhanced through industrialization (NOAA, 1991).

In keeping with the requirements of the RI/FS process, and based on the potential ecological effects of the chemical stressors (identified above), a suite of assessment and measurement endpoints were identified as important in the ecological risk assessment. As indicated in Table 3.2-2, these include the vitality of pelagic, epibenthic, and infaunal communities, as represented by common and/or natural resource species in the vicinity of the Housatonic River. Target receptors chosen to be representative of these habitats/trophic modes are discussed in Section 3.4.

Exposure point measurements employed as indicators of the assessment endpoints are presented in Table 3.2-3. The exposure point measurements were selected based on their relevance to:

- The assessment endpoint and receptors of concern, their relevance to expected modes of action, and effects of CoCs;
- Determination of adverse ecological effects;
- Availability of practical methods for their evaluation; and
- Their usefulness in extrapolating to other endpoints.

Most of these measurement endpoints have been used in other studies, and have proven to be informative indicators of ecological status in aquatic and estuarine systems with respect to the stressors identified as important in this assessment. Many serve a dual purpose in that they provide information relevant to two or more assessment endpoints.

In addition to the measurement endpoints used to evaluate the occurrence of, or potential for, adverse ecological effects, exposure point measurements were employed to evaluate exposure conditions. As shown in Table 3.2-3, these exposure point measurements include chemistry measurements made in environmental media (porewater, sediment, and biota), as well as geochemical attributes of exposure media which may influence the availability of contaminants to receptors.

These measurement endpoints will be used as the weight-of-evidence in the exposure assessment component of the risk characterization summary. The protocols

and methods used to evaluate measurement endpoints and exposure point measurements are discussed further in Section 4.0.

3.3. Contaminants of Concern

Proposed Contaminants of Concern (CoCs) have been identified for this investigation using a rationale which links the source (Raymark waste) to potential aquatic receptors in Areas C-F through plausible exposure pathways. The selection process involves sequential evaluation of target analyte concentrations, first considering the frequency of detection, then elevation relative to minimum effects benchmarks. For analytes lacking benchmarks, site concentrations were compared against reference concentrations.

Benchmarks are numerical criteria or guidelines which establish chemical concentrations presumed to be protective of biological systems. For derivation of CoCs in this ERA, site sediment concentrations are of primary consideration as sediments are the major reservoir for CoC constituents. Available (*i.e.*, nationally recognized) benchmarks for sediments include the Apparent Effects Threshold (AET; U.S. EPA, 1989d), Effects Range-Low and Effects Range-Median (Long and Morgan, 1990, Long *et al.*, 1995), and Equilibrium Partitioning-based Aquatic Life criteria (EqP-AL; U.S. EPA 1989e, Adams *et al.*, 1992). The AET approach uses data from matched chemistry and biological effects measures, and is the concentration of a selected chemical above which statistically significant biological effects are expected to occur (U.S. EPA, 1989d). Effects Range-Low (ER-L) and Effects Range-Median (ER-M) are benchmarks representing the 10th and 50th percentiles, respectively, of ranked chemical concentrations (predicted or measured) at which biological effects were observed. The Equilibrium Criteria-Aquatic Life Approach (Adams *et al.*, 1992) predicts effects in porewater for non-ionic organic contaminants based on the water quality benchmark, accounting for partitioning between dissolved and particulate phases. For three of the chemicals measured in site sediments for this ERA, the EPA has promulgated criteria known as Sediment Quality Criteria (SQC; DiToro *et al.*, 1991). Each benchmark has advantages and disadvantages as well as differing degrees of applicability for various chemical groups.

For this ERA, the lowest of the matrix-specific benchmarks was used as the screening value for each compound (Table 3.3-1). In most cases, the NOAA ER-L was the minimum benchmark value. For chemical constituents lacking benchmarks, sediment concentrations measured at reference locations were used as the basis of comparison.

Results of the screening process for the development of the aquatic sediment CoC list are summarized in Table 3.3-2. Frequency of detection was calculated as the percentage of total site samples analyzed which had detected concentrations. The range of concentrations reported for site data excludes non-detected values. One-half

of the Sample Quantitation Limit was substituted for non-detected values calculating the mean concentration of each compound for both the site and reference stations. The 95% upper confidence limit was calculated according to standard statistical procedures (Snedecor and Cochran, 1980), assuming a one-tailed distribution (*i.e.*, only data exceeding the upper 95% confidence limit are of interest). Where the 95% UCL was greater than the site maximum concentration, the maximum concentration was used to screen against benchmark or reference data. Lastly, information on bioaccumulation persistence and toxicity was also considered in the selection of CoCs.

For metals, all analytes with the exception of arsenic and silver had maximum concentrations in bulk sediments which exceeded reference. All PAH analytes except 2-methylnaphthalene, biphenyl, naphthalene, were found to exceed either benchmarks or reference area concentrations. For PCBs, 23of 27congeners were detected at a frequency >5%, In contrast, only four of 24 pesticides were similarly detected; analytes retained as CoCs include o,p'-DDE, and p,p'-DDD, -DDE and -DDT. It should be noted that this list of CoCs is conservative in that the screening procedure involved maximum contaminant concentrations and conservative benchmark concentrations. Final consideration of CoCs for offshore exposure media will be made following completion of the Exposure Assessment (see Section 4.0 of this report).

3.4. Receptors of Concern

Identification of ecological systems/species/receptors of concern (hereafter collectively termed "receptors of concern") involved evaluations of the importance of each potential receptor (or "candidate") to the ecology of the Raymark study area, its sensitivity to stressors associated with the site, and its aesthetic, recreational, and commercial importance as a natural resource. The site characterization for Raymark study area identified a number of aquatic systems and habitat types (Section 3.1.3). The nature of chemical stressors originating from Raymark study area operations suggests that several ecological receptors may be potentially at risk, including:

- Nearshore habitats directly adjacent to Raymark study area areas;
- Pelagic communities, including plankton and fish;
- Infaunal benthic communities in sediment depositional areas;
- Soft- and hard-bottom epibenthic communities; and
- Commercially, recreational, and/or aesthetically important natural resource species.

The aquatic systems and habitats of Raymark study area include primarily subtidal environments, sand- or silt- bottom, with some eelgrass covering the intertidal

environments. The identification of aquatic systems and habitats potentially at risk from Raymark study area contaminants provides a natural progression to the selection of target receptors of concern for this ecological risk assessment (Table 3.4-1). These target receptors, and the rationale for their selection, include:

- Ribbed mussel (*Geukensia demissus*), oyster (*Crassostrea virginica*): These species are locally abundant and ecologically important filter-feeding bivalves found in intertidal and subtidal habitats. It is an important food source for birds, fish, shellfish and aquatic mammals. Mussels and oysters are surrogates for epibenthic species in the intertidal environment, where they are potentially exposed to water-borne and particulate-bound contaminants.

- Mummichogs (*Fundulus heteroclitus)*: These species are locally abundant and ecologically important estuarine fish which feed opportunistically upon both animals and plants, and have limited home range due to territorial behaviors. When abundant, they may be an important food source for birds and other fish, and are a surrogate for other pelagic fish species potentially exposed to water-borne and bulk sediment contaminants.

- Benthic community: The benthic community (including sponges, mollusks, segmented worms, arthropods (including crustaceans), starfish, and chordates (tunicates and fish)) is an ecologically important, potentially rich assemblage of species with numerous life histories and feeding strategies. It is an important food source for birds, fish, and benthic and epibenthic invertebrates. The benthic community is potentially exposed to contaminants in bulk sediments, pore water, and the water column.

Many of these receptors are important resource species for the Housatonic River, but also can be considered surrogate receptors for larger groups of species. For instance, the oyster is an important commercial species for Connecticut, as well as an indicator species for infaunal bivalves in general. However, as discussed in a later section, not all of these species occurred at all of the sampling stations.

Stressors introduced to the bay may indirectly affect avian receptors. For example, bivalves and fish contaminated with chemicals may be consumed by shorebirds, resulting in direct or indirect biological effects. For this reason, avian and mammalian target receptors of concern include:

- Raccoon (*Raydon arduatus*). This species is a common local semi-aquatic mammal which feeds upon invertebrates and fish, in addition to anthropogenic sources. The raccoon is a top-level carnivore and represents other aquatic mammals (*e.g.,* shrew, muskrat, otter, mink) that might occur on site. Impacts on this species will be assessed through food web modeling.

- Black-crowned Night Heron (*Nycticorax nycticorax*). This species is a local avian aquatic predator which feed upon invertebrates and fish. The heron is a top-level carnivore and represents wading shorebirds (*e.g.*, snowy egret, *Egretta thula*) which are principally piscivorus and may also occur on site. Impacts on these species will be assessed through food web modeling.

3.5. Conceptual Models

Conceptual models are developed to provide a framework for hypotheses concerning how a given stressor might cause ecological impacts on receptors of concern (U.S. EPA, 1992a). Two models, comprising the overall conceptual model for this assessment, have been developed; one related to the primary contaminant pathways from the Raymark site and the other, being the generalized exposure scenario for ecological receptors of concern.

The transport pathway model (NOAA, 1998) describes the primary release of contaminants from the Raymark industrial operation in the form of waste materials and site soils used as fill (Figure 3.5-1). Some releases due to direct discharge from waste lagoon may also be involved. The primary receiving media pertinent to aquatic receptors are surface waters, wetland soils and surface sediments. Through chemical partitioning processes (erosion, sorption, bioaccumulation) the CoCs are further disseminated throughout the primary habitat (wetlands, marsh, ponds, riverine sediments). Air transport of chemical pollutants bound to soil and dust particles also may occur, however, this pathway is not addressed in the current investigation.

Conceptual models are developed to provide a framework for hypotheses concerning how a given stressor might cause ecological impacts on receptors of concern (U.S. EPA, 1992a). Four models, comprising the overall conceptual model for this assessment, have been developed using a tiered strategy. Models in the initial tiers are more general and inherently carry greater uncertainty, whereas the more complex fourth-tier models have greater complexity and certainty for the specific pathways being evaluated. In the process of further refinement of models in subsequent tiers, hypotheses are retained or rejected based on existing knowledge of contaminants and receptors of concern. However, as previously indicated, the conceptual model approach in this assessment addresses only current conditions and levels of activity at the site, and does not address future use scenarios involving fundamentally different conditions or activities at the site.

Tier I represents the general north to south gradient of chemical contamination in the Housatonic River adjacent to Ferry Creek (Areas A-B) and areas which are the focus of the present investigation (Figure 3.5-2). Although many sources contribute to this gradient, and local sources may influence specific stressor concentrations anywhere in the river, this model suggests that contaminant concentrations in the immediate vicinity of Areas C-F should be evaluated within the context of the ecology of

the entire lower river to evaluate the extent and significance of the Raymark site on the ecology of the river and adjoining wetlands, marshes and ponds.

The second tier model describes details of the aquatic behavior of contaminants hypothesized to exert ecological effects within the system (Figure 3.5-3). The model arrows indicate that the short-term behavior of contaminants in the water column depends on their solubility, degradation rates, and sorption to particulate matter. Bound contaminants may be transported with the current in association with particles, but may also settle to the bottom in localized depositional areas, such as those areas suspected for the Raymark study area. Individual molecules may remain in a dissolved state or will adsorb and desorb in a dynamic fashion, maintaining an apparent equilibrium relative to sorption state. Dissolved contaminants are transported to other parts of the study area by prevailing current patterns.

Once on the bottom, local currents may result in bedload transport of sediment, resulting in a further redistribution of the contaminants. Subsequent deposition of uncontaminated particles may bury earlier settling particles, and eventually block them from contact with ecological systems. Chemical-specific partitioning dynamics will occur in the sediments and interstitial (pore) waters in response to the geochemical conditions (*e.g.,* redox potential) of those sediments. Contaminants may be available to biological systems in the water column, pore water, and surficial sediments, resulting in direct toxicological effects and/or biological uptake and transfer through food webs.

Resuspended sediments can potentially contribute colloidal and/or dissolved organic contaminants to the water column in elutriate preparations and, presumably, during sediment resuspension. This evaluation, however, addresses only current conditions and levels of activity at the site, it does not address future use scenarios involving fundamentally different conditions or activities at the site. One possible zone where such exposure concentrations might temporarily exist is at the sediment water interface during major storm events or during mechanical disruption, in which case CoCs may produce adverse exposure to aquatic receptors.

Based on this generalized conceptual model, ecosystems potentially at risk are hypothesized to include nearshore habitats, pelagic, benthic and epibenthic communities, and natural resource species. In addition, stressor partitioning dynamics suggest that the assessment of potential risks to receptors should focus on CoCs associated with depositional sediments. Stressors which conform to this model of contaminant behavior include metals, organic contaminants such as PAHs, PCBs, and OCPs.

The description of stressor dynamics suggests potential risks to the aforementioned systems to be highest in areas adjacent to Raymark study area. Although risks to other ecological systems present in the study area cannot be dismissed, this conceptual model focuses the assessment on ecosystems considered to be directly influenced by depositional sediments.

The initial two tiers describe the origin, transport and fate of stressors at different spatial and temporal scales. To complete the model, receptors and stressors specific to the Raymark study area are added in the third and final tier, which describes receptor-specific exposure pathways hypothesized for the site for the receptors of concern identified in Table 3.4-1. These models were developed for receptors by ecological habit (pelagic, epibenthic, infaunal, aquatic mammal, avian aquatic predator), and their respective exposure pathways (Figure 3.5-4 to Figure 3.5-7). Measurement endpoints directly evaluating the effects of CoCs on mammals or avian aquatic species are not included in this study. However, an evaluation of the potential impacts to species group from ingestion of prey organisms hypothesized to be part of the exposure pathways to the predator is characterized through measurement of the spatial distribution and residue concentration of the food source. Hence, relevant issues for this trophic group with regard to the ERA framework are addressed from this perspective.

3.6. Sampling and Analysis Summary

This section describes data collection and analysis activities required to develop the information base necessary to complete the ecological risk assessment. As discussed in Section 2, the sampling was needed to acquire chemistry and toxicity data for surficial sediments in the area adjacent to the Raymark study area, and to gather biological data to assess the condition of potentially affected receptors. Measurements of organic and metal contaminant concentrations associated with sediments and organisms, were performed in conjunction with toxicity studies to assess the potential impact of Raymark study area on the biota. All sediment and biota samples were collected April of 1999. In the sections that follow, a brief discussion is presented on station locations and selection rationale, and sampling and analysis methods for chemical, geotechnical and biological endpoints.

3.6.1. Sediment and Biota Collection

Sediments. The locations of the sampling stations in Raymark study area are shown in Figure 3.6-1 to 3.6-5. A total of 16 stations for the four areas were selected. The stations were selected to confirm previous results of high concentrations of contaminants, to fill data gaps from prior studies and to characterize gradients in contaminant concentrations. Reference data from the Great Meadow station GM-08 was utilized from a prior study (SAIC, 1998). This area is approximately 5 km south of Raymark study area, and does not have a direct hydrologic connection with the Housatonic River system.

A sample collection and laboratory analysis summary for the Raymark study area ERA is shown in Table 3.6-1. Surface grabs were collected at all stations and were analyzed for bulk sediment and porewater chemistry (metals and organics), toxicity (amphipod survival), SEM/AVS, grain size, and total organic carbon (TOC).

At each station, surficial sediment (0-15 cm) from an undisturbed area was collected by scoop. The majority of samples were collected at low tide. For non-tidal areas (Areas E and F) approximately 2-3 grabs were needed to collect sufficient sample for both chemistry and toxicity analyses. The grab sampler was "washed-down" with sea water between grabs. Between stations, the sampling apparatus was rinsed in sequence with distilled water, 1:1 nitric acid, methanol and de-ionized water. The material from the samples was returned to the laboratory on ice, composited in a 12-liter polyethylene bucket, homogenized with a titanium stirrer for ~30 seconds, and then subsampled into precleaned containers for organic and inorganic chemistry, SEM/AVS analyses and toxicity studies.

Biota. Biota sampling activity for the Raymark study area investigation is summarized in Table 3.6-1. Target species at the intertidal stations (Areas C and D) were ribbed mussels and mummichogs. However, only ribbed mussels were successfully obtained at all stations except D-5 as mummichogs were not present when samples were collected. Mussels were collected at Station HB-1, adjacent to D-5, as none were present at D-5.

Grain Size. Percentages of sand, silt and clay in sediment samples from each station were determined as described in the Work Plan. Samples were pre-treated for removal of carbonates and organics, and then sieved using the Elzone Model 180XY particle size analyzer. The grain size data were used to assist in interpretation of chemical distribution data for lithologic variation influence.

Total organic content. Estimation of sediment total organic carbon (TOC) content was accomplished by determining the weight lost on ignition at 550°C. Details of the method are contained in the work plan. The total organic content data were used to normalize the organic contaminant data. These measurements were used to assess organic contaminant bioavailability and equilibrium between sediment and porewater.

3.6.2. Sediment and Biota Chemical Analyses

Sediments. The concentrations of selected metals, PCB congeners, pesticides and PAHs in surface and core sediment samples were determined as described in the Work Plan (refer to Table 3 of Work Plan). In addition, the concentrations of Simultaneously Extractable Metals (SEM) and Acid Volatile Sulfides (AVS) in these sediments were determined.

Tissues. Tissue analyses included the same suite as determined in sediments. Shell and exoskeletal material were not analyzed for any species. Bivalve and tissue were frozen whole after collection and analyzed whole. Samples of bivalves from the collection were selected at random and were resected at the organic or inorganic lab depending on the analysis. In addition, the lipid content of the tissue was determined for use in bioaccumulation factor calculations.

Toxicity Testing. All surface grab samples were evaluated for bulk sediment toxicity using the amphipod 10-day acute test. A complete description of these test methods is contained in the Work Plan.

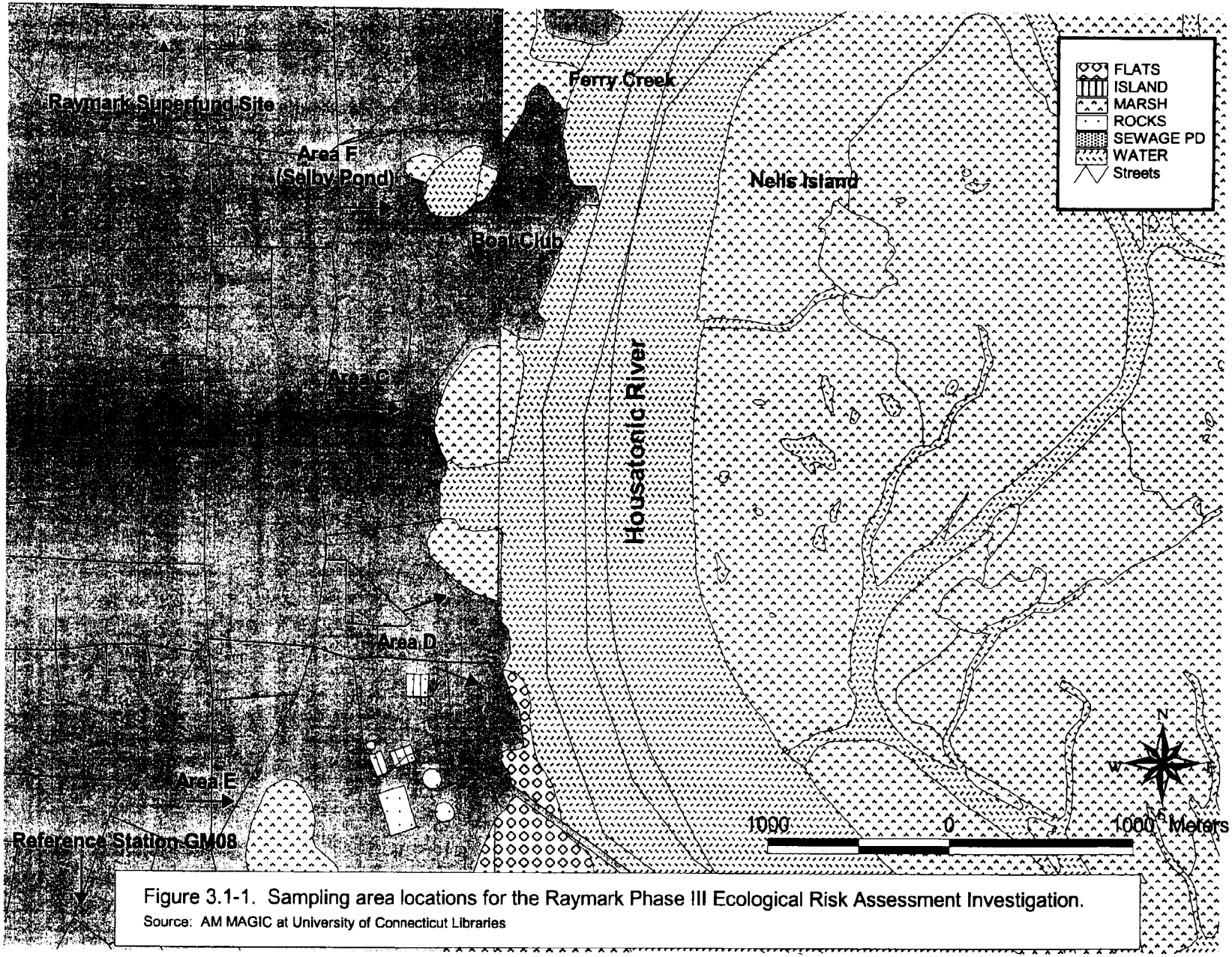


Figure 3.1-1. Sampling area locations for the Raymark Phase III Ecological Risk Assessment Investigation.

Source: AM MAGIC at University of Connecticut Libraries

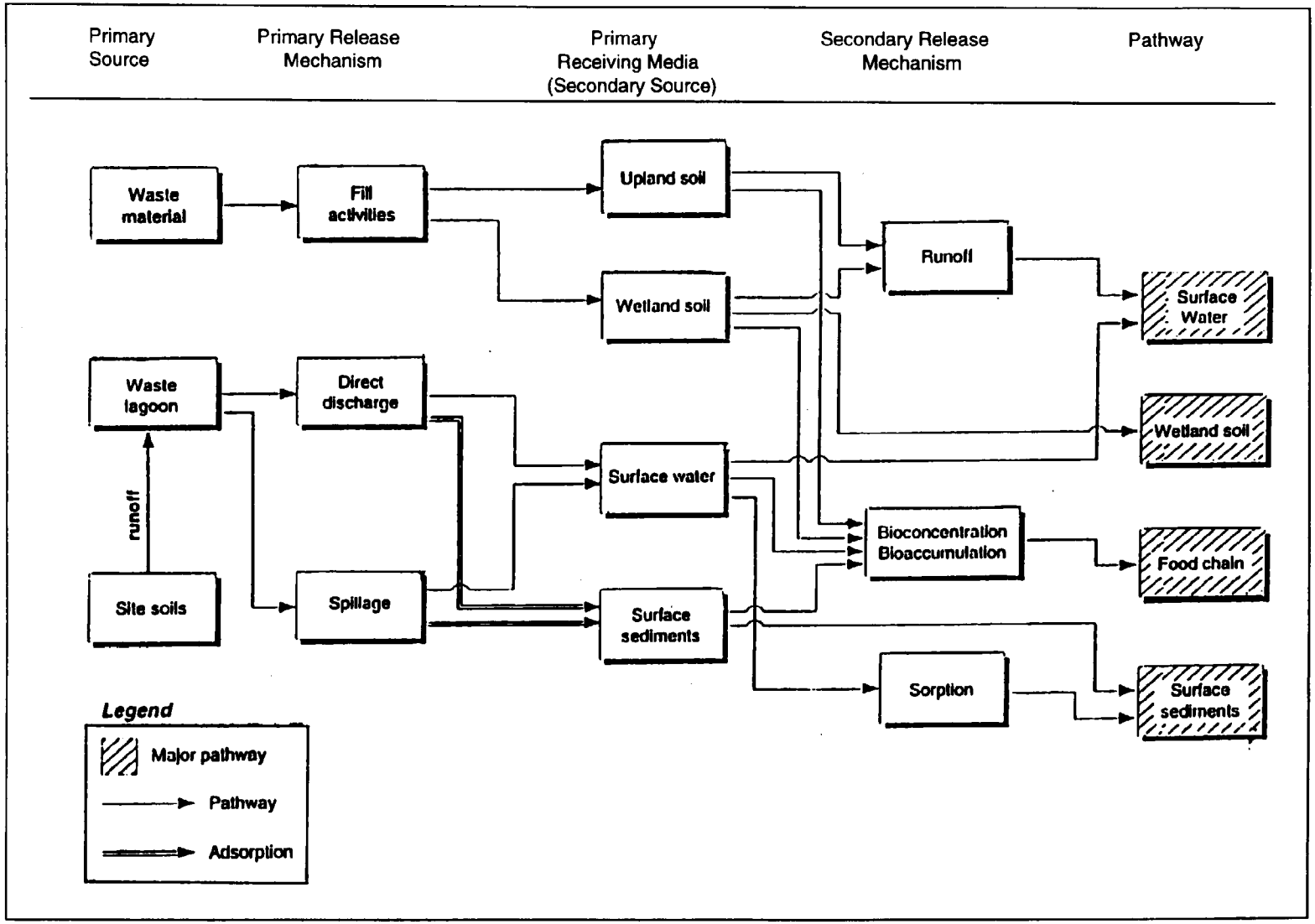


Figure 3.5-1. Primary contaminant pathways from the Raymark Industries Site.
Source: NOAA, 1998.

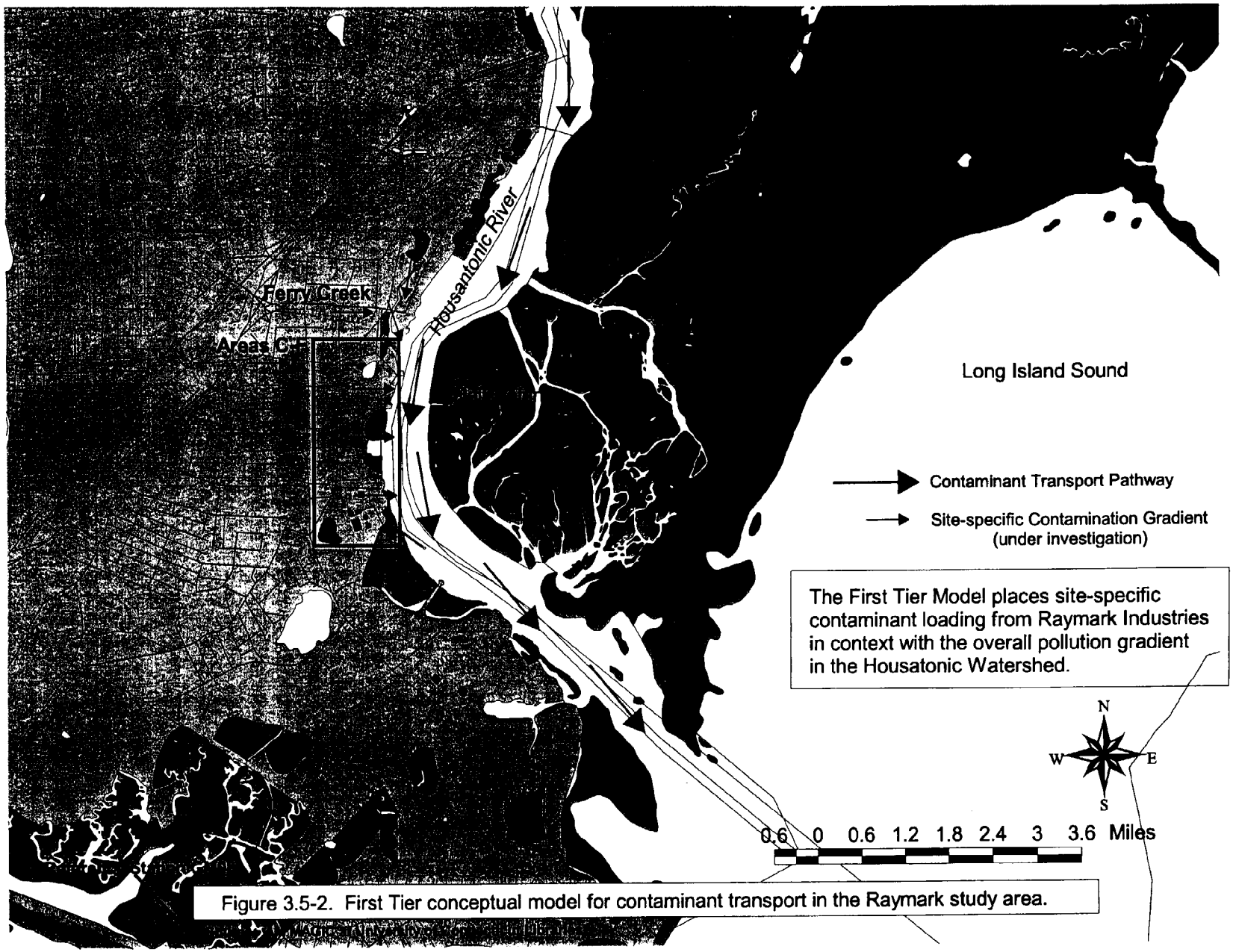


Figure 3.5-2. First Tier conceptual model for contaminant transport in the Raymark study area.

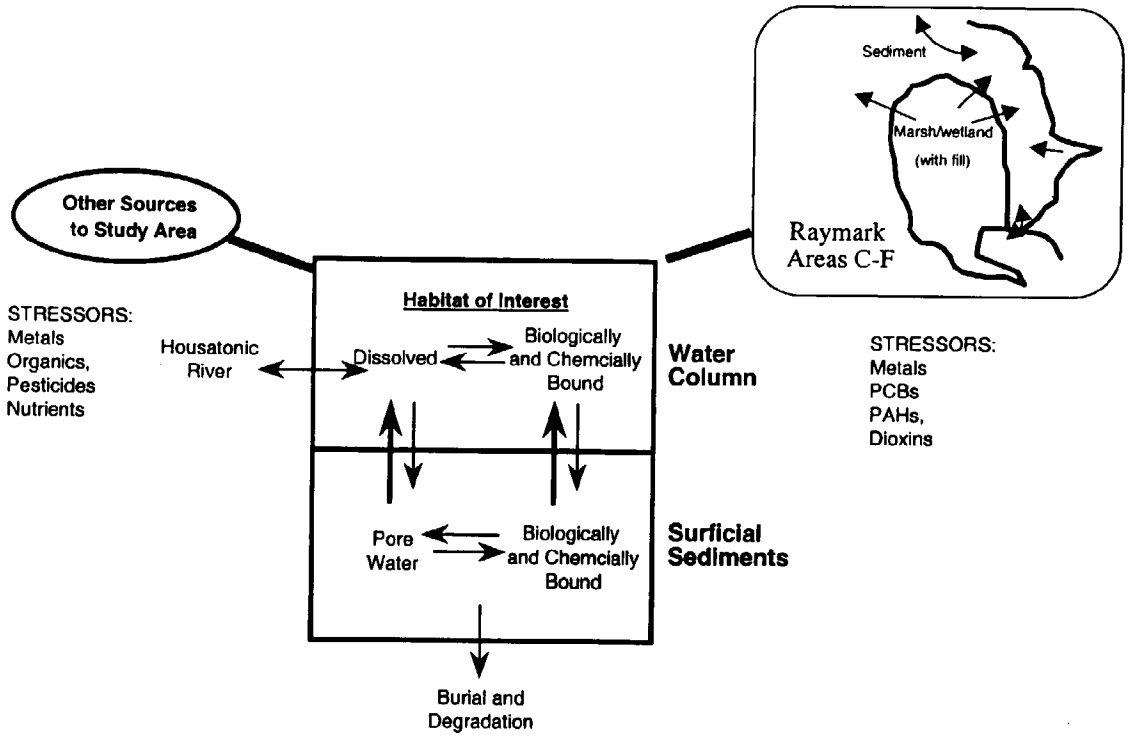


Figure 3.5-3. Second Tier conceptual model of contaminant behavior for the Raymark ERA.

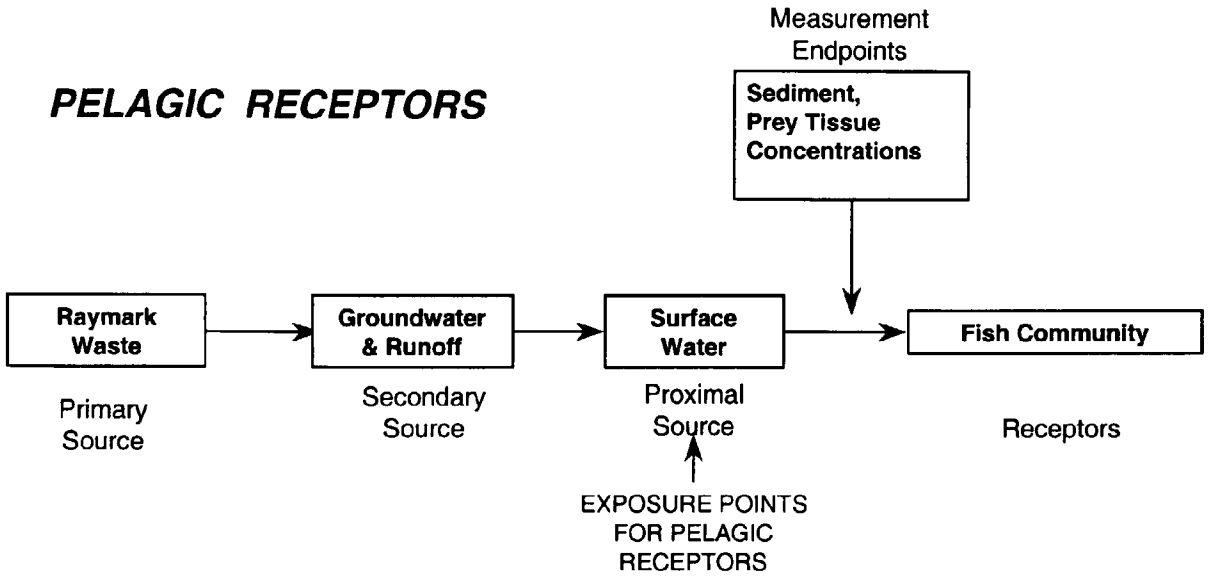


Figure 3.5-4. Third tier conceptual model of contaminant transport for Raymark Areas C-F: Exposure pathway to pelagic receptors.

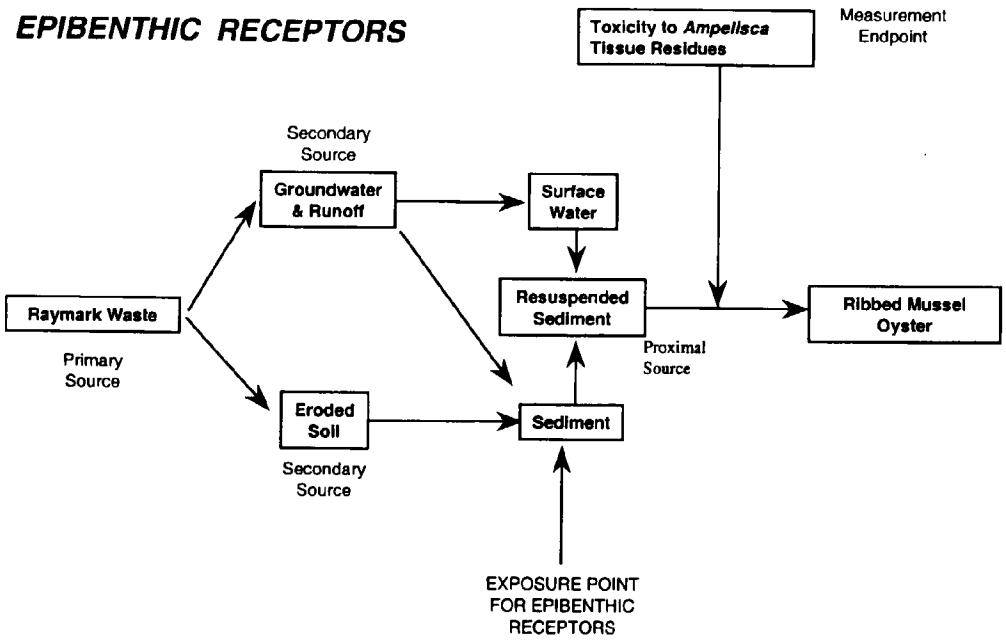


Figure 3.5-5. Third tier conceptual model of contaminant transport for Raymark Areas C-F: Exposure pathway to epibenthic receptors.

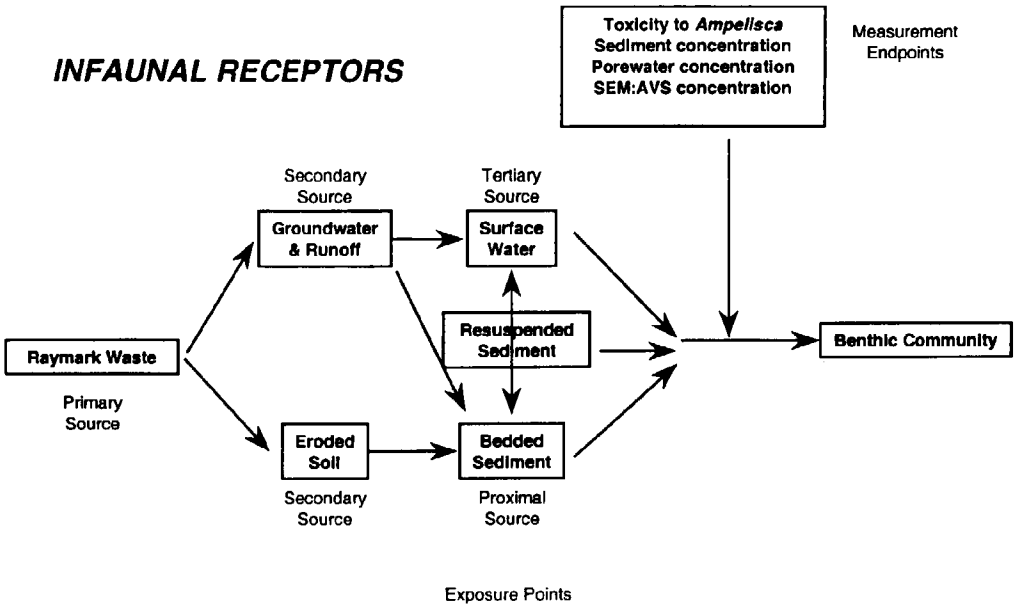


Figure 3.5-6. Third tier conceptual model of contaminant transport for Raymark Areas C-F: Exposure pathway to infaunal receptors.

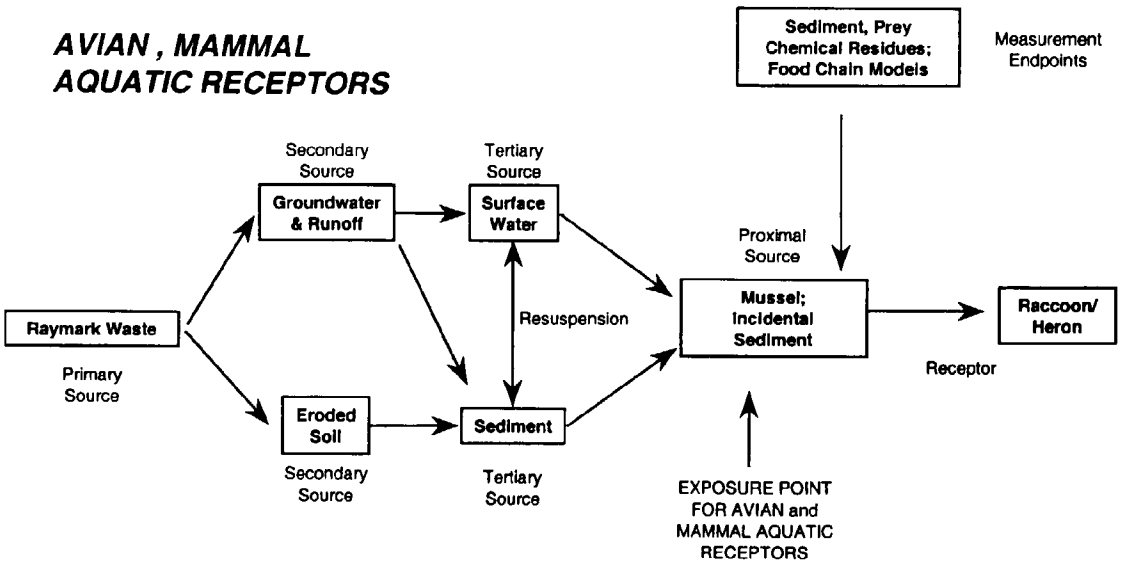


Figure 3.5-7. Third tier conceptual model of contaminant transport for Raymark Areas C-F: Exposure pathway to avian and mammal aquatic receptors.

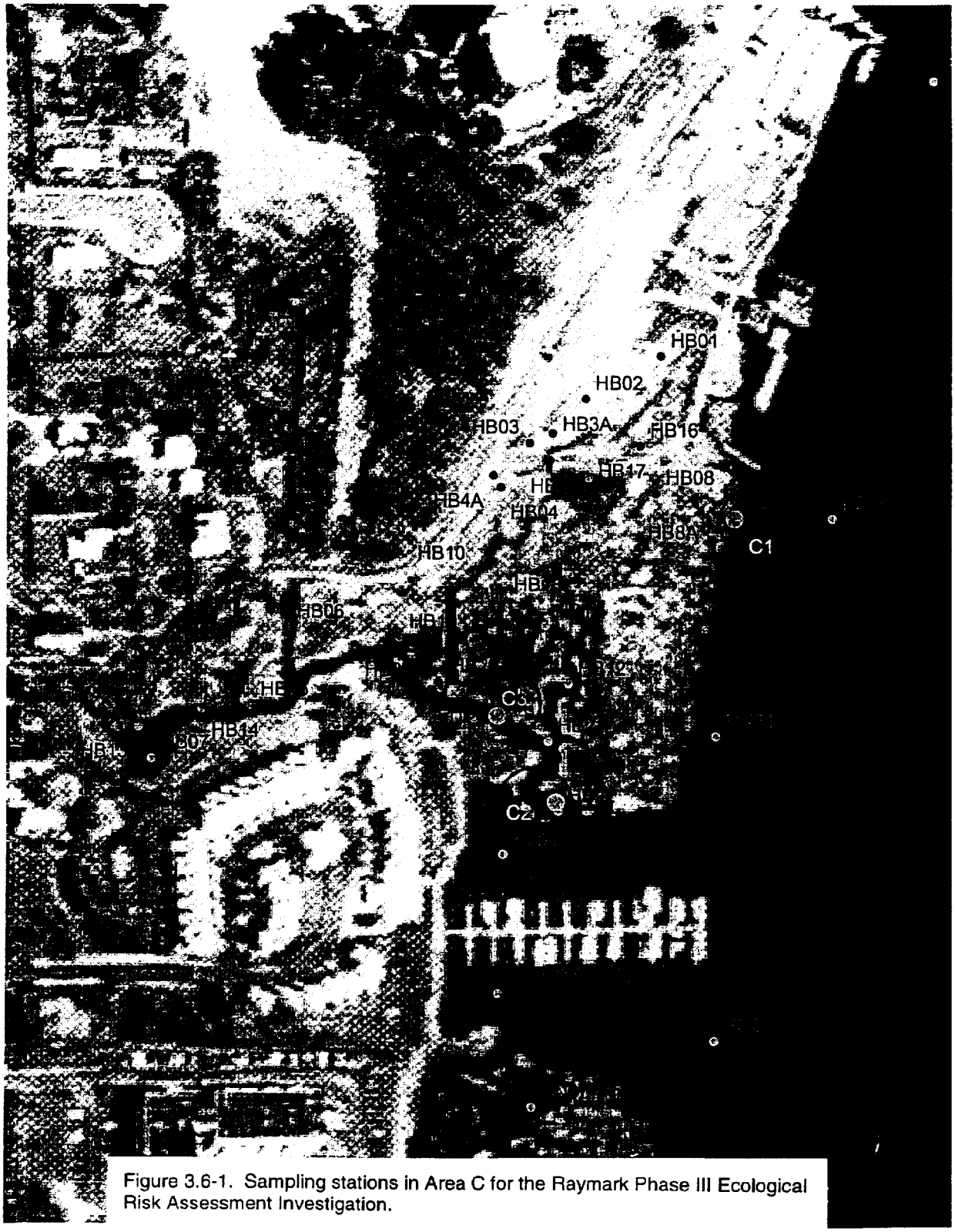


Figure 3.6-1. Sampling stations in Area C for the Raymark Phase III Ecological Risk Assessment Investigation.

Figure 3.6-2a. Sampling stations in Area D for the Raymark Phase III Ecological Risk Assessment Investigation.

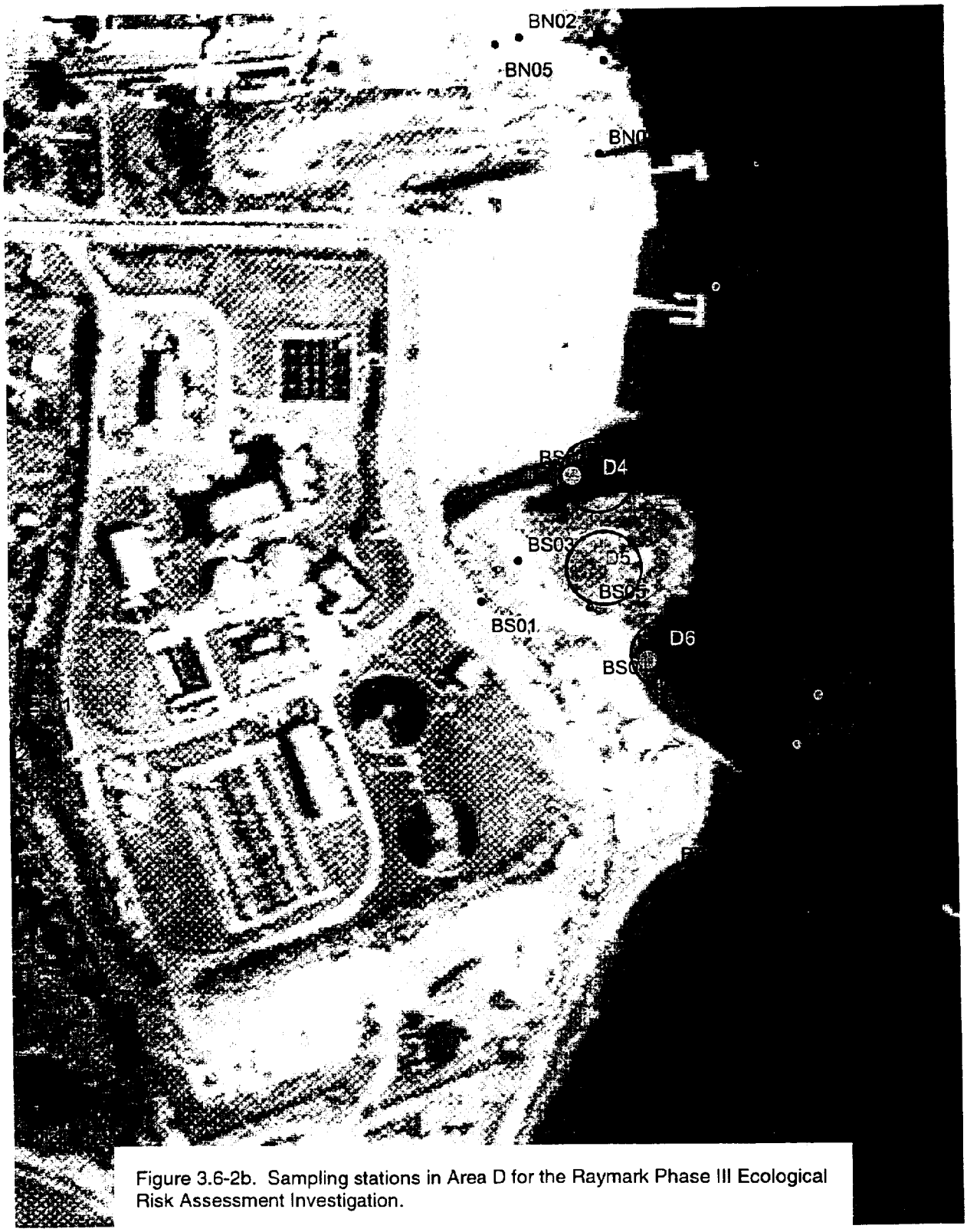


Figure 3.6-2b. Sampling stations in Area D for the Raymark Phase III Ecological Risk Assessment Investigation.

Figure 3.6-3. Sampling stations in Area E for the Raymark Phase III Ecological Risk Assessment Investigation.

Figure 3.6-4. Sampling stations in Area F for the Raymark Phase III Ecological Risk Assessment Investigation.

Table 3.2-1. Target analytes for chemical characterization for the Raymark Phase III Ecological Risk Assessment Investigation.

Metals

Reporting Name	Analyte	CAS NO	Sediment Analysis Method	Sediment MDL mg/Kg dry	Sediment Reporting Limit mg/Kg dry
As	Arsenic	7440-38-2	GFAA 7060	0.04	0.5
Cd	Cadmium	7440-43-9	GFAA 7131	0.06	0.2
Cr	Chromium	7440-47-3	ICP 6010B	0.34	1.0
Cu	Copper	7440-50-8	GFAA 7211	0.1	0.5
Pb	Lead	7439-92-1	GFAA 7421	0.14	0.2
Hg	Total Mercury (cold vapor)	7439-97-6	CVAA 7471	0.005	0.006
Ni	Nickel	7440-02-0	ICP 6010B	1.2	2.0
Ag	Silver	7440-22-4	GFAA 7761	0.03	0.2
Zn	Zinc	7440-66-6	ICP 6010B	2.0	0.43

SEM:AVS

Reporting Name	Analyte	CAS NO	Analysis Method	Sediment MDL mg/Kg dry	Sediment Reporting Limit mg/Kg dry
SEM-Cu	Copper	7440-50-8	ICP 6010B	0.53	2.0
SEM-Cd	Cadmium	7440-43-9	ICP 6010B	0.23	0.5
SEM-Pb	Lead	7439-92-1	ICP 6010B	5.0	10
SEM-Ni	Nickel	7440-02-0	ICP 6010B	0.99	5
SEM-Zn	Zinc	7440-66-6	ICP 6010B	5.9	10
AVS	Acid Volatile Sulfide		Ag_2S Probe EPA, 1992	0.1	20

SEM Reporting Limits based on 2.0 g digested, 50% moisture, and 100-mL final volume.

Table 3.2-1. Continued.

Metals

Reporting Name	Analyte	CAS NO	Tissue Analysis Method	Tissue MDL mg/Kg dry	Tissue Reporting Limit mg/Kg dry
As	Arsenic	7440-38-2	GFAA 7060	0.056	0.5
Cd	Cadmium	7440-43-9	GFAA 7131	0.027	0.2
Cr	Chromium	7440-47-3	GFAA 7191	0.11	0.5
Cu	Copper	7440-50-8	GFAA 7211	0.62	0.5
Pb	Lead	7439-92-1	GFAA 7421	0.047	0.2
Hg	Total Mercury (cold vapor)	7439-97-6	CVAA 7471	0.024	0.006
Ni	Nickel	7440-02-0	GFAA 7521	0.47	0.5
Ag	Silver	7440-22-4	GFAA 7761	0.016	0.2
Zn	Zinc	7440-66-6	ICP 6010B	3.6	0.43

Metals

Reporting Name	Analyte	CAS NO	Porewater Analysis Method	Seawater MDL µg/L	Seawater Reporting Limit µg/L dry
As	Arsenic	7440-38-2	Hydride 7061	0.30	4.0
Cd	Cadmium	7440-43-9	ICP 6010B	0.15	0.5
Cr	Chromium	7440-47-3	GFAA 7191	0.60	10
Cu	Copper	7440-50-8	GFAA 7211	0.26	0.6
Pb	Lead	7439-92-1	GFAA 7421	0.007	0.04
Ni	Nickel	7440-02-0	ICP 6010B	0.59	2.0
Ag	Silver	7440-22-4	ICP 6010B	0.12	1.0
Zn	Zinc	7440-66-6	ICP 6010B	4.0	0.59

Porewater limits are based on having 50 mL porewater after filtering to chelate/extract and preconcentrate for analysis.

Table 3.2-1. Continued.

PAHs

Reporting Name	Analyte	CAS NO	Sediment MDL µg/Kg dry	Sediment Reporting Limit µg/Kg dry
T167NAP	1,6,7-Trimethylnaphthalene	2245387	0.10	2
M1NAPH	1-Methylnaphthalene	90120	0.11	2
M1PHEN	1-Methylphenanthrene	832699	0.16	2
D26NAPH	2,6-Dimethylnaphthalene	581420	0.17	2
M2NAPH	2-Methylnaphthalene	91-57-6	0.19	2
ACENAPH	Acenaphthene	83-32-9	0.14	2
ACENAPL	Acenaphthylene	208-96-8	0.13	2
ANTHRAC	Anthracene	120-12-7	0.23	2
BENAAN	Benzo(a)anthracene	56-55-3	0.19	2
BENAPYR	Benzo(a)pyrene	50-32-8	0.065	2
BENBFLU	Benzo(b)fluoranthene	205-99-2	0.34	2
BENEPYR	Benzo(e)pyrene	192972	0.19	2
BGHIPER	Benzo(g,h,i)perylene	191-24-2	0.19	2
BENKFLU	Benzo(k)fluoranthene	207-08-9	0.47	2
BIPHEN	Biphenyl	92524	0.46	2
CHRYSEN	Chrysene	218-01-9	0.18	2
DBAHANT	Dibenz(a,h)anthracene	53-70-3	0.26	2
FLUORAN	Fluoranthene	206-44-0	0.22	2
FLUOREN	Fluorene	86-73-7	0.082	2
I123CDP	Indeno(1,2,3-cd)pyrene	193-39-5	0.093	2
NAPH	Naphthalene	91-20-3	0.28	2
PERYL	Perylene	198550	0.13	2
PHENAN	Phenanthrene	85-01-8	0.22	2
PYRENE	Pyrene	129-00-0	0.24	2

Methods follow NS&T Program guidelines, and SW-846 Method 8270 Modified. Reporting limits based on 20-g sample, 50% moisture content, and 2-mL final extract volume.

Table 3.2-1. Continued.

PAHs

Reporting Name	Analyte	CAS NO	Tissue MDL µg/Kg dry	Tissue Reporting Limit µg/Kg dry
T167NAP	1,6,7-Trimethylnaphthalene	2245387	5.3	10
M1NAPH	1-Methylnaphthalene	90120	3.8	10
M1PHEN	1-Methylphenanthrene	832699	10	10
D26NAPH	2,6-Dimethylnaphthalene	581420	4.3	10
M2NAPH	2-Methylnaphthalene	91-57-6	6.1	10
ACENAPH	Acenaphthene	83-32-9	4.2	10
ACENAPL	Acenaphthylene	208-96-8	4.5	10
ANTHRAC	Anthracene	120-12-7	3.7	10
BENAAN	Benzo(a)anthracene	56-55-3	9.3	10
BENAPYR	Benzo(a)pyrene	50-32-8	4.7	10
BENBFLU	Benzo(b)fluoranthene	205-99-2	5.5	10
BENEPYR	Benzo(e)pyrene	192972	5.2	10
BGHIPER	Benzo(g,h,i)perylene	191-24-2	3.7	10
BENKFLU	Benzo(k)fluoranthene	207-08-9	5.5	10
BIPHEN	Biphenyl	92524	3.6	10
CHRYSEN	Chrysene	218-01-9	4.2	10
DBAHANT	Dibenz(a,h)anthracene	53-70-3	5.4	10
FLUORAN	Fluoranthene	206-44-0	6.6	10
FLUOREN	Fluorene	86-73-7	4.9	10
I123CDP	Indeno(1,2,3-cd)pyrene	193-39-5	5.1	10
NAPH	Naphthalene	91-20-3	5.1	10
PERYL	Perylene	198550	3.4	10
PHENAN	Phenanthrene	85-01-8	7.6	10
PYRENE	Pyrene	129-00-0	6.0	10

Methods follow NS&T Program guidelines and SW-846 Method 8270 Modified. Reporting limits based on 20-g sample, 90% moisture content, and 2-mL final extract volume.

Table 3.2-1. Continued.

PCB congeners

Reporting Name	Analyte	CAS NO	Sediment MDL µg/Kg dry	Sediment Reporting Limit µg/Kg dry
PCB008	8 (2 4)	34883437	0.063	1
PCB018	18 (2 2'5)	37680652	0.29	1
PCB028	28 (2 4 4')	7012375	0.025	1
PCB029	29 (2 4 5)	15862074	NA	1
PCB044	44 (2 2'3 5')	41464395	0.18	1
PCB050	50 (2 2' 4 6)	62796650	NA	1
PCB052	52 (2 2'5 5)	35693993	0.083	1
PCB066	66 (2 3'4 4')	32598100	0.030	1
PCB077	77(3 3' 4 4')	32598133	0.047	1
PCB087	87(2 2' 3 4 5')	38380028	0.063	1
PCB101	101 (2 2'4 5 5')	37680732	0.086	1
PCB104	104 (2 2' 4 6 6')	56558168	NA	1
PCB105	105 (2 3 3'4 4')	32598144	0.040	1
PCB118	118 (2 3'4 4'5)	31508006	0.046	1
PCB126	126 (3 3' 4 4' 5)	57465288	0.060	1
PCB128	128 (2 2'3 3'4 4')	39380073	0.15	1
PCB138	138 (2 2'3 4 4'5)	35065282	0.075	1
PCB153	153 (2 2'4 4'5 5')	35065271	0.069	1
PCB154	154(2 2 4 4' 5 6')	60145224	NA	1
PCB170	170 (2 2'3 3'4 4'5)	35065306	0.14	1
PCB180	180 (2 2'3 4 4'5 5')	35065293	0.058	1
PCB187	187 (2 2'3 4'5 5'6)	52663680	0.046	1
PCB188	188 (2 2' 3 4' 5 6 6')	74487857	NA	1
PCB195	195 (2 2'3 3'4 4'5 6)	52663782	0.052	1
PCB200	200 (2 2' 3 3' 4 5 6 6')	40186718	NA	1
PCB206	206 (2 2'3 3'4 4'5 5'6)	40186729	0.050	1
PCB209	209 (2 2'3 3'4 4'5 5'6 6')	2051243	0.075	1

Methods follow NS&T Program guidelines and SW-846 Method 8082 Modified. Reporting limit based on 20-g sample, 50% moisture, 2-mL final extract volume; lower reporting limits may be achieved if required by the project QAPjP.

NA – Not available, congener not included in most recent MDL study.

Table 3.2-1. Continued.

PCB congeners

Reporting Name	Analyte	CAS NO	Tissue MDL µg/Kg dry	Tissue Reporting Limit µg/Kg dry
PCB008	8 (2 4)	34883437	5.1	5
PCB018	18 (2 2'5)	37680652	2.6	5
PCB028	28 (2 4 4')	7012375	3.5	5
PCB029	29 (2 4 5)	15862074	NA	5
PCB044	44 (2 2'3 5')	41464395	6.1	5
PCB050	50 (2 2' 4 6)	62796650	NA	5
PCB052	52 (2 2'5 5)	35693993	1.4	5
PCB066	66 (2 3'4 4')	32598100	3.2	5
PCB077	77(3 3' 4 4')	32598133	2.7	5
PCB087	87(2 2' 3 4 5')	38380028	1.7	5
PCB101	101 (2 2'4 5 5')	37680732	1.7	5
PCB104	104 (2 2' 4 6 6')	56558168	NA	5
PCB105	105 (2 3 3'4 4')	32598144	1.5	5
PCB118	118 (2 3'4 4'5)	31508006	5.3	5
PCB126	126 (3 3' 4 4' 5)	57465288	0.67	5
PCB128	128 (2 2'3 3'4 4')	39380073	4.8	5
PCB138	138 (2 2'3 4 4'5)	35065282	3.4	5
PCB153	153 (2 2'4 4'5 5')	35065271	4.2	5
PCB154	154(2 2 4 4' 5 6')	60145224	NA	5
PCB170	170 (2 2'3 3'4 4'5)	35065306	NA	5
PCB180	180 (2 2'3 4 4'5 5')	35065293	5.4	5
PCB187	187 (2 2'3 4'5 5'6)	52663680	1.7	5
PCB188	188 (2 2' 3 4' 5 6 6')	74487857	NA	5
PCB195	195 (2 2'3 3'4 4'5 6)	52663782	3.9	5
PCB200	200 (2 2' 3 3' 4 5 6 6')	40186718	NA	5
PCB206	206 (2 2'3 3'4 4'5 5'6)	40186729	1.0	5
PCB209	209 (2 2'3 3'4 4'5 5'6 6')	2051243	0.75	5

Methods follow NS&T Program guidelines and SW-846 Method 8082 Modified. Reporting limit based on 20-g sample, 90% moisture, 2-mL final extract volume.

NA – Not available, congener not included in most recent MDL study.

Table 3.2-1. Continued.

OCPs

Reporting Name	Analyte	CAS NO	Sediment MDL µg/Kg dry	Sediment Reporting Limit µg/Kg dry
ABHC	Alpha-BHC	319846	0.014	1
ACHLOR	Alpha-Chlordane	5103719	0.022	1
BBHC	Beta-BHC	319857	0.026	1
DBHC	Delta-BHC	319868	0.017	1
DIELDRIN	Dieldrin	6057	0.049	1
ENDOSFN1	Endosulfan I	959988	0.022	1
ENDOSFN2	Endosulfan II	33213659	0.031	1
ENDOSO4	Endosulfan Sulfate	1031078	0.059	1
ENDRIN	Endrin	72208	0.039	1
ENDRINAD	Endrin Aldehyde	7421934	0.048	1
GBHC	Gamma-BHC(Lindane)	58899	0.014	1
GCHLOR	Gamma-Chlordane	5103742	0.030	1
HPTCHLOR	Heptachlor	76448	0.037	1
HPTEPOX	Heptachlor Epoxide	1024573	0.032	1
MTXYCHLR	Methoxychlor	72435	0.23	5
TOXPHNE	Toxaphene	8001352	NA	10
ALDRIN	Aldrin	309002	0.012	1
HCB	Hexachlorobenzene	118-74-1	NA	1
MIREX	Mirex	2385855	NA	1
DDD_PP	p,p'-DDD	72548	0.026	1
DDE_PP	p,p'-DDE	72559	0.033	1
DDT_PP	p,p'-DDT	50293	0.030	1
DDD_OP	o,p'-DDD	53190	NA	1
DDE_PP	o,p'-DDE	3424826	NA	1
DDT_PP	o,p'-DDT	789026	NA	1

Methods follow NS&T Program guidelines and SW-846 Method 8081 Modified. Reporting limit based on 20-g sample, 50% moisture, 2-mL final extract volume; lower reporting limits may be achieved if required by the project QAPjP.

NA – Not available, pesticide not included in most recent MDL study.

Table 3.2-1. Continued.

OCPs

Reporting Name	Analyte	CAS NO	Tissue MDL µg/Kg dry	Tissue Reporting Limit µg/Kg dry
ABHC	Alpha-BHC	319846	0.80	5
ACHLOR	Alpha-Chlordane	5103719	1.6	5
BBHC	Beta-BHC	319857	NA	5
DBHC	Delta-BHC	319868	NA	5
DIELDRIN	Dieldrin	6057	1.4	5
ENDOSFN1	Endosulfan I	959988	0.81	5
ENDOSFN2	Endosulfan II	33212659	1.3	5
ENDOSO4	Endosulfan Sulfate	1031078	NA	5
ENDRIN	Endrin	72208	1.6	5
ENDRINAD	Endrin Aldehyde	7421934	NA	5
GBHC	Gamma-BHC(Lindane)	58899	1.3	5
GCHLOR	Gamma-Chlordane	5103742	0.99	5
HPTCHLOR	Heptachlor	76448	1.6	5
HPTEPOX	Heptachlor Epoxide	1024573	0.82	5
MTXYCHLR	Methoxychlor	72435	NA	25
TOXPHNE	Toxaphene	8001352	NA	50
ALDRIN	Aldrin	309002	0.40	5
HCB	Hexachlorobenzene	118-74-1	NA	5
MIREX	Mirex	2385855	2.1	5
DDD_PP	p,p'-DDD	72548	1.1	5
DDE_PP	p,p'-DDE	72559	1.0	5
DDT_PP	p,p'-DDT	50293	1.8	5
DDD_OP	o,p'-DDD	53190	1.6	5
DDE_PP	o,p'-DDE	3424826	1.5	5
DDT_PP	o,p'-DDT	789026	1.2	5

Methods follow NS&T Program guidelines and SW-846 Method 8081 Modified. Reporting limit based on 20-g sample, 90% moisture, 2-mL final extract volume.

Tissue MDL studies are in progress and due for completion 04/05/99.

Table 3.2-1. Continued.

Dioxins/Dibenzofurans

Reporting Name	Analyte	CAS NO	Sediment Reporting Limit ng/g dry
1,2,3,4,6,7,8,9-OCDD	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	3268879	0.001
1,2,3,4,6,7,8,9-OCDF	1,2,3,4,6,7,8,9-Octachlorodibenzofuran	39001020	0.001
1,2,3,4,6,7,8-HpCDD	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	35822394	0.001
1,2,3,4,6,7,8-HpCDF	1,2,3,4,6,7,8-Heptachlorodibenzofuran	67562394	0.001
1,2,3,4,7,8,9-HpCDF	1,2,3,4,7,8,9-Heptachlorodibenzofuran	55673897	0.001
1,2,3,4,7,8-HxCDD	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	39227286	0.001
1,2,3,4,7,8-HxCDF	1,2,3,4,7,8-Hexachlorodibenzofuran	70648269	0.001
1,2,3,6,7,8-HxCDD	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	57653857	0.001
1,2,3,6,7,8-HxCDF	1,2,3,6,7,8-Hexachlorodibenzofuran	57117449	0.001
1,2,3,7,8,9-HxCDD	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	19408743	0.001
1,2,3,7,8,9-HxCDF	1,2,3,7,8,9-Hexachlorodibenzofuran	72918219	0.001
1,2,3,7,8-PeCDD	1,2,3,7,8-Pentachlorodibenzo-p-dioxin	40321764	0.001
1,2,3,7,8-PeCDF	1,2,3,7,8-Pentachlorodibenzofuran	57117416	0.001
2,3,4,6,7,8-HxCDF	2,3,4,6,7,8-Hexachlorodibenzofuran	60581345	0.001
2,3,4,7,8-PeCDF	2,3,4,7,8-Pentachlorodibenzofuran	57117314	0.001
2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746016	0.001
2,3,7,8-TCDF	2,3,7,8-Tetrachlorodibenzofuran	51207319	0.001
Dibenzofuran	Dibenzofuran	132649	0.001
Total HpCDD	Total HpCDD	37871004	0.001
Total HpCDF	Total HpCDF	38998753	0.001
Total HxCDD	Total HxCDD	34465468	0.001
Total HxCDF	Total HxCDF	55684941	0.001
Total PeCDD	Total PeCDD	36088229	0.001
Total PeCDF	Total PeCDF	30402154	0.001
Total TCDD	Total TCDD	41903575	0.001
Total TCDF	Total TCDF	55722275	0.001

Methods follow SW-846 Method 1613B.

Table 3.2-2. Assessment and measurement endpoints for the Raymark Phase III Ecological Risk Assessment Investigation.

Assessment Endpoint/Receptor	Measurement Endpoint
Vitality of Pelagic Community:	Tissue Residues
Vitality of Epibenthic Community: Ribbed Mussel Oyster	Tissue Residues Bulk Sediment Toxicity to Amphipods Sediment Chemistry Ammonia Total Organic Carbon Grain Size SEM and AVS
Vitality of Infaunal Community Benthic Community	Bulk Sediment Toxicity to Amphipods Sediment Chemistry Porewater Ammonia Total Organic Carbon Grain Size SEM and AVS
Viatality of Avian Aquatic Black-crowned night heron	Sediment Chemistry Tissue Residues
Vitality of Semi-Aquatic Mammal Raccoon	Sediment Chemistry Tissue Residues

Table 3.3-1. Target analyte sediment benchmarks for the Raymark Phase III Ecological Risk Assessment Investigation.

		Sediment Benchmark[1]					
Group	Target Analyte[2]	AET[3]	AL[4]	ER-L[5]	ER-M[6]	SQC[7]	PEL[8]	MB[9]
Metals	Cadmium	5.1		1.20	9.6			1.20
	Chromium	260		81.00	370			81.00
	Copper	390		34.00	270			34.00
	Lead	450		46.70	218			46.70
	Mercury	0.41		0.15	0.71			0.15
	Nickel	140		20.90	51.6			20.90
	Zinc	410		150.00	410			150.00
PAHs	1,6,7-Trimethylnaphthalene							NA
	1-Methylnaphthalene							NA
	1-Methylphenanthrene							NA
	2,6-Dimethylnaphthalene							NA
	Acenaphthene	500	1300	16.00	500	1300	88.9	16
	Acenaphthylene	1300		44.00	640		128	44
	Anthracene	960		85.30	1100		245	85
	Benzo(a)anthracene	1600		261.00	1600		693	261
	Benzo(a)pyrene	1600		430.00	1600		763	430
	Benzo(b+k)fluoranthene	3600						3600
	Benzo(e)pyrene							NA
	Benzo(g,h,i)perylene							NA
	Chrysene	2800		384.00	2800		846	384
	Dibenz(a,h)anthracene	230		63.40	260		135	63
	Fluoranthene	2500	6200	600.00	5100	6200	1494	600
	Fluorene	540	540	19.00	540		144	19
	High Molecular Weight PAHs	17000		1700.00	9600		6676	1700
	Indeno(1,2,3-cd)pyrene	690						690
	Low Molecular Weight PAHs	5200		552.00	3160		1442	552
	Perylene							NA
	Phenanthrene	1500	1800	240.00	1500	1800	544	240
	Pyrene	3300	97000	665.00	2600		1398	665
	Total PAHs			4022.00	44792			4022
PCBs	PCB Sum of Congeners x 2	1000		22.7	180		189	22.7
Dioxins	Mammal			2.50	25.00			
	Fish			60.00	100.00			
	Bird			21.00	210.00			
Pesticides	o,p'-DDE	9.00		2.20	27.00		374	2.20
	p,p'-DDE	9.00		2.20	27.00		374	2.20
	p,p'-DDD	16.00		1.58	27.00		7.81	1.58
	p,p'-DDT	34.00		1.58	27.00		4.77	1.58

1 - Benchmark units (dry wt): Metals (MET) - µg/g; PAHs, PCBs, Pesticides - ng/g.
2 - Analytes measured by SAIC (1998) and in present study.
3 - AET = Apparent Effects Threshold (PTI Environmental Services, 1988).
4 - AL = Equilibrium Partitioning- Aquatic Life (based on 1 % TOC) (U.S. EPA, 1989e; Adams, 1992; and Kimerle and Barnett, 1992).
5 - ER-L = NOAA Effects Range-Low (Long and Morgan, 1990; Long *et al.*, 1995).
6 - ER-M = NOAA Effects Range-Median (Long *et al.*, 1995).
ER-M Benchmark for DDT series assumed to be the same as for o,p'-DDE.
7 - SQC = EPA Sediment Quality Criteria (U.S. EPA, 1993a,b,c).
8 - PEL = Probable Effects Levels
9 - MB = Minimum of Benchmarks.
NA = Benchmark not available.

Table 3.3-2. Sediment data summary and selection of contaminants of concern (CoCs) for the Raymark Phase III Ecological Risk Assessment Investigation.

CLASS	ANALYTE	SEDIMENT[1]											
		FREQUENCY OF DETECTION AT SITE			RANGE OF SITE CONCENTRATION[a]		MEAN SITE CONCENTRATION[b]	SITE 95% UPPER CONFIDENCE LIMIT	MEAN REFERENCE CONCENTRATION[b]	MINIMUM BENCHMARK[c]	95% UCL or MAX CONCENTRATION[d]		FREQUENCY OF DETECTION > 5%?	IS TARGET ANALYTE A CoC?
		# Detects	# Samples	%	Minimum	Maximum					Exceeds Minimum Benchmark?	Exceeds Reference?		
MET	Arsenic	17	17	100%	1.60	13.60	6.25	11.67	17.90	8.20	YES	NO	YES	NO
	Cadmium	13	17	76%	0.12	2.60	0.53	1.72	1.50	1.20	YES	YES	YES	YES
	Chromium	17	17	100%	9.70	390	86.19	256	231	81.00	YES	YES	YES	YES
	Copper	17	17	100%	22.60	1560	284	903	561	34.00	YES	YES	YES	YES
	Lead	17	17	100%	7.30	571	144	376	158	46.70	YES	YES	YES	YES
	Mercury	17	17	100%	0.04	2.50	0.50	1.44	1.20	0.15	YES	YES	YES	YES
	Nickel	17	17	100%	5.50	65.90	20.45	43.04	37.40	20.90	YES	YES	YES	YES
	Silver	16	17	94%	0.16	4.50	0.84	2.58	3.00	1.00	YES	NO	YES	NO
	Zinc	17	17	100%	41.50	982	236	659	292	150	YES	YES	YES	YES
PAH	1,6,7-Trimethylnaphthalene	17	17	100%	3.00	100.00	23.88	72.22					YES	YES
	1-Methylnaphthalene	16	17	94%	4.00	220	32.68	118				-	YES	YES
	1-Methylphenanthrene	17	17	100%	14.00	410	124	334				-	YES	YES
	2,6-Dimethylnaphthalene	16	17	94%	4.00	170	31.88	105				-	YES	YES
	2-Methylnaphthalene	15	17	88%	4.00	140	42.71	112				-	YES	YES
	Acenaphthene	16	17	94%	3.00	1100	108	550	330	70.00	YES	NO	YES	NO
	Acenaphthylene	14	17	82%	18.00	940	246	693	330	16.00	YES	YES	YES	YES
	Anthracene	17	17	100%	3.00	3200	546	1970	330	44.00	YES	YES	YES	YES
	Benzo(a)anthracene	13	17	76%	9.00	11000	1715	6302	330	85.30	YES	YES	YES	YES
	Benzo(a)pyrene	17	17	100%	7.00	9700	1622	5627	190	261	YES	YES	YES	YES
	Benzo(b)fluoranthene	16	17	94%	8.00	8800	1963	6121	230	430	YES	YES	YES	YES
	Benzo(e)pyrene	14	17	82%	7.00	7800	1309	4440	400	3600	YES	YES	YES	YES
	Benzo(g,h,i)perylene	17	17	100%	6.00	7200	1227	4223				-	YES	YES
	Benzo(k)fluoranthene	17	17	100%	6.00	8500	1024	4357	74.00			-	YES	YES
	Biphenyl	13	17	76%	3.00	340	46.65	197	390			-	YES	YES
	Chrysene	17	17	100%	8.00	8700	1583	5258		1100	NO	-	YES	NO
	Dibenz(a,h)anthracene	17	17	100%	14.00	1500	266	895	220	384	YES	YES	YES	YES
	Fluoranthene	17	17	100%	17.00	21000	3387	12391	330	63.40	YES	YES	YES	YES
	Fluorene	17	17	100%	4.00	920	111	501	330	600	YES	YES	YES	YES
	HMW PAHs	17	17	100%	57.00	54300	8980	31791	330	19.00	YES	YES	YES	YES
	Indeno(1,2,3-cd)pyrene	17	17	100%	6.00	8500	1444	4990		1700	YES	-	YES	YES
	LMW PAHs	17	17	100%	26.00	14920	2854	10376	110	890	YES	YES	YES	YES
	Naphthalene	13	17	76%	3.00	210	63.00	168		552	YES	-	YES	YES
	Perylene	17	17	100%	14.00	2400	407	1390	330	160	YES	NO	YES	NO
	Phenanthrene	17	17	100%	12.00	11000	1738	6699		-		-	YES	YES
	Pyrene	17	17	100%	18.00	17000	3156	10886	120	240	YES	YES	YES	YES
	Total PAHs	17	17	100%	144	127320	22216	76909	410	665	YES	YES	YES	YES
									7094	4022	YES	YES	YES	YES

Notes 1 - Data summary includes surface and core data collected during the present study.

2 - Concentration and benchmark units (dry wt): Metals (MET) - ug/g; PAHs, PCBs, Pesticides (PST) - ng/g

a - The range of concentrations reported for site data excludes non-detected values.

b - 1/2 Sample Quantitation Limits substituted for non-detects when calculating mean of site and reference station data.

c - Minimum benchmark - see report Table 3.3-1.

d - If 95% UCL is greater than the Maximum Concentration, as indicated with a "+", then Maximum Concentration is used to screen against benchmark or reference, as available.

NA = Benchmark Not Available.

- = Value for comparison is not available.

Table 3.3-2. Sediment data summary and selection of contaminants of concern (CoCs) for the Raymark Phase III Ecological Risk Assessment Investigation.

		SEDIMENT[2]												
CLASS	ANALYTE	FREQUENCY OF DETECTION AT SITE			RANGE OF SITE CONCENTRATION[a]		MEAN SITE CONCENTRATION[b]	SITE 95% UPPER CONFIDENCE LIMIT	MEAN REFERENCE CONCENTRATION[b]	MINIMUM BENCHMARK[c]	95% UCL or MAX CONCENTRATION[d]		FREQUENCY OF DETECTION > 5%?	IS TARGET ANALYTE A CoC?
		# Detects	# Samples	%	Minimum	Maximum					Exceeds Minimum Benchmark?	Exceeds Reference?		
PCB	PCB008	2	17	12%	170	320	29.98	170			-	-	YES	YES
	PCB018	1	17	6%	3000	3000	179				-	-	YES	YES
	PCB028	5	17	29%	1.30	1700	105	779	5.80		-	YES	YES	YES
	PCB029	0	17	0%							-	-	NO	NO
	PCB044	6	17	35%	4.50	820	85.99	397			-	-	YES	YES
	PCB050	0	17	0%							-	-	NO	NO
	PCB052	6	17	35%	2.30	2000	179	1045			-	-	YES	YES
	PCB066	7	17	41%	1.90	2100	131	964			-	-	YES	YES
	PCB077	2	17	12%	3.50	4.70	6.32	30.32	1.70		+	-	YES	YES
	PCB087	3	17	18%	9.40	680	43.64	319			-	-	YES	YES
	PCB101	9	17	53%	4.70	2700	185	1252			-	-	YES	YES
	PCB104	0	17	0%							-	-	NO	NO
	PCB105	12	17	71%	0.95	580	46.31	267	5.40		-	YES	YES	YES
	PCB118	10	17	59%	0.97	1600	108	741	11.00		-	YES	YES	YES
	PCB126	6	17	35%	1.30	140	12.14	67.10			-	-	YES	YES
	PCB128	1	17	6%	520	520	32.95				+	-	YES	YES
	PCB138	13	17	76%	0.94	1900	128	879			-	-	YES	YES
	PCB153	13	17	76%	1.10	1500	106	698			-	-	YES	YES
	PCB154	1	17	6%	2.00	2.00	5.99				+	-	YES	YES
	PCB170	3	17	18%	2.90	400	26.72	185	1.80		-	YES	YES	YES
	PCB180	12	17	71%	2.40	330	31.31	180	6.20		-	YES	YES	YES
	PCB187	13	17	76%	1.50	150	16.66	77.00			-	-	YES	YES
	PCB188	9	17	53%	1.20	210	16.76	99.11			-	-	YES	YES
	PCB195	5	17	29%	1.10	5.40	6.60	30.48			+	-	YES	YES
	PCB200	0	17	0%							-	-	NO	NO
	PCB206	8	17	47%	4.00	31.00	12.82	39.14			+	-	YES	YES
	PCB209	2	17	12%	3.00	6.50	6.38	30.39	1.30		+	-	YES	YES
	Sum of PCB Congeners X 2	17	17	100%	9.60	10600	2981	19453	247	22.70	+	YES	YES	YES
PEST	Aldrin	0	17	0%								-	NO	NO
	Alpha-BHC	0	17	0%						0.99		YES	NO	NO
	Alpha-Chlordane	0	17	0%						4.79		YES	NO	NO
	Beta-BHC	0	17	0%						0.99		YES	NO	NO
	Delta-BHC	0	17	0%						0.99		YES	NO	NO
	Dieldrin	0	17	0%						4.30		YES	NO	NO
	Endosulfan I	0	17	0%								-	NO	NO
	Endosulfan II	1	17	6%	1.90	1.90	1.35			14.00	+	NO	YES	NO
	Endosulfan Sulfate	0	17	0%								-	NO	NO
	Endrin	0	17	0%						42.00		YES	NO	NO
	Gamma-BHC (Lindane)	0	17	0%						1.00		YES	NO	NO
	Gamma-Chlordane	0	17	0%						4.79		YES	NO	NO
	Heptachlor	0	17	0%								-	NO	NO
	Heptachlor Epoxide	0	17	0%								-	NO	NO
	Hexachlorobenzene	1	17	6%	11.00	11.00	1.83			22.00	+	NO	YES	NO
	Methoxychlor	0	17	0%						19.00		YES	NO	NO
	Mirex	0	17	0%								-	NO	NO
	o,p'-DDD	0	17	0%						1.58		YES	NO	NO
	o,p'-DDE	1	17	6%	7.30	7.30	1.83			2.20	+	YES	YES	YES
	o,p'-DDT	0	17	0%						1.58		YES	NO	NO
	p,p'-DDD	9	17	53%	1.80	120	18.08	70.87		1.58		YES	YES	YES
	p,p'-DDE	3	17	18%	4.00	99.00	8.65	48.56		2.20		YES	YES	YES
	p,p'-DDT	2	17	12%	4.20	24.00	2.70	11.99		1.58		YES	YES	YES
	Toxaphene	0	17	0%						100.00		YES	NO	NO

Notes 1 - Data summary includes surface and core data collected during the present study.

2 - Concentration and benchmark units (dry wt): Metals (MET) - ug/g; PAHs, PCBs, Pesticides (PST) - ng/g.

a - The range of concentrations reported for site data excludes non-detected values.

b 1/2 - Sample Quantitation Limits substituted for non-detects when calculating mean of site data.

c - Minimum benchmark - see report Table 3.3-1.

d - If 95% UCL is greater than the Maximum Concentration, as indicated with a "+", then Maximum Concentration is used to screen against benchmark or reference, as available.

NA = Benchmark Not Available.

- = Site concentrations of organic contaminants were compared to reference concentrations only when no appropriate benchmark was available.

Table 3.4-1. Habitats and ecological systems/species/receptors of concern for the Raymark Phase III Ecological Risk Assessment Investigation.

Habitat	Ecological System/Species/Receptor of Concern
Pelagic	fish community
Epibenthic	ribbed mussel (*Modiolus demissus*) oyster (Crassostria virginica)
Infaunal	benthic community
Avian Aquatic	black-crowned night heron (*Nycticorax nycticorax*)
Semi-Aquatic Mammal	raccoon (*Procyon lotor*)

Table 3.6-1. Sample collection and analysis summary for the Raymark Phase III Risk Assessment Investigation.

Station	Sediment Chemistry			Tissue Chemistry	Geotechnical		Bioassay
	Bulk Sediment[1]		SEM/AVS	Mussels	Grain Size	TOC	
	SED	PW	SUR	MUS	SUR	SUR	AMP
C-1	1	1	1	1	1	1	1
C-2	1	1	1	1	1	1	1
C-3	1	1	1	1	1	1	1
D-1	1	1	1	1	1	1	1
D-2	1	1	1	1	1	1	1
D-3	1	1	1	1	1	1	1
D-4	1	1	1	1	1	1	1
D-5	1	1	1		1	1	1
D-6	1	1	1	1	1	1	1
D-6-FD	1	1	1		1	1	1
E-1	1	1	1		1	1	1
E-2	1	1	1		1	1	1
E-3	1	1	1		1	1	1
E-4	1	1	1		1	1	1
F-1	1	1	1		1	1	1
F-2	1	1	1		1	1	1
HB-1[2]				1			
F-3	1	1	1		1	1	1
Reference[3]	1	1	1		1	1	1
TOTAL	18	18	18	9	18	18	18

1 - Bulk sediment testing for metals and organics.
2 - See Appendix F-1.
3 - Reference Station = GM08 (SAIC, 1998).
SED = Surface Sediment (0-6 cm)
PW = Porewater
MUS = Ribbed Mussel
TOC = Total Organic Carbon
AMP = Sediment Amphipod (*Ampelisca*) Survival Test

4.0. EXPOSURE ASSESSMENT

Exposure assessment for the Raymark investigation involves the evaluation of the site-specific conceptual models with respect to hypothesized exposure pathways to target receptors and includes the direct measurement of exposure point concentrations along these pathways. For this assessment, Raymark fill is considered to be the primary source of CoCs in study areas. In addition to direct measurement of chemistry, other exposure measures are assessed to aid in the interpretation of chemical exposure conditions. Methods and QA/QC considerations and protocols relevant to analytical chemistry are presented in Section 3.6.

Exposure information derived from previous investigations at the site has been evaluated for applicability to this assessment and used as appropriate. Accompanying the description of these data is a discussion of the comparability of the various data sets as well as an evaluation of the uncertainty associated with the exposure analyses.

Exposure Assessment results are described below in four sections: an examination of contaminant sources and exposure pathways of CoCs (Section 4.1), analyses of geotechnical characteristics of the sites (Section 4.2), estimates of exposure point concentrations (Section 4.3), and an analysis of the uncertainty related to the exposure assessment (Section 4.4). Exposure modeling and risk characterization for avian and mammalian predators have been consolidated into Section 6.3.3 and Section 6.3.4 in order to enhance the clarity of the presentation.

4.1. Sources and Exposure Pathways of CoCs

Several exposure pathways are likely to exist from contaminant sources associated with historical activities at Raymark. Early characterization studies of Raymark contaminants (discussed in Section 3.1) have concluded that PAHs, PCBs, numerous metals, chlorinated pesticides (*e.g.*, p,p'-DDE), and dioxins were present in concentrations which may potentially represent significant ecological risk.

Sources and exposure pathways for contaminants from Raymark to the aquatic environment and associated biota were introduced in Section 3.5 as a series of conceptual models. First Tier exposure pathways are related to the relative magnitude of site-specific sources versus regional sources. Initial exposure pathways as defined by the Second Tier model are expected to occur primarily via surface and ground water flows from the study area. The Third Tier model describes the behavior of dissolved and particle-bound contaminants in the aquatic environment, including transport by and/or association with surface water, sediments, porewater, and biota. Finally, the Fourth Tier model identifies sources and exposure pathways for biological receptors, including: surface water exposures to pelagic organisms such as fish and filter-feeding infauna and epifauna; soil (particle), sediment, and porewater exposures to bottom-dwelling fish, infauna and epifauna; and the potential for fish and invertebrate prey to

function as proximal sources and exposure points for upper level predators such as fish-eating birds and mammals.

Contaminant exposure routes for aquatic biota can involve exposure through water, sediments, elutriates and porewater via partitioning across cell membranes, incidental contact or feeding mode ingestion of sediments (*e.g.*, by bottom deposit-feeding organisms), and consumption of contaminated prey. Thus, it is important to identify the behavior and potential effects of CoCs as a key part of the risk assessment. Based on the general models described above, a more detailed evaluation of exposure pathways can be derived for specific classes of CoCs as related to their chemical and physical behavior, and characteristics such as specific bioaccumulation potentials. The toxicity of CoCs is addressed in Section 5.1.

Some organic contaminants identified in source samples, including the organochlorinated pesticides (OCPs) such as p,p'-DDE and the polychlorinated biphenyls (PCBs), share similar properties in that they are characterized by relatively low solubilities in water and high solubilities in lipid phases of animal tissues. The low water solubilities tend to result in a net transfer of such compounds from aqueous to particulate phases, with subsequent accumulation in sediments and porewater (via partitioning; Clayton *et al.*, 1977). Transfer of this type of CoC to organisms living on or in the sediments can occur through direct uptake (*e.g.*, dermal contact or sediment ingestion), through partitioning to interstitial porewater, or through food web transfer. Because of the tendency for these compounds to remain adsorbed to sediments, there should be relatively low dissolved-phase concentrations above the sediments, thereby minimizing direct exposures to pelagic organisms via the water column.

It is notable that respiratory surfaces of water-breathing organisms, such as fish and invertebrates, provide an effective transfer mechanism for these lipid-soluble organic contaminants between the aqueous environment and lipid-rich tissues. Thus, the concentrations of highly lipid-soluble organic contaminants in these organisms may be somewhat controlled by these transfer mechanisms. Consequently, contaminant concentrations in these species may be more dependent on the lipid content as related, for example, to reproductive condition, than on magnification of the chemical within a food web (Clayton *et al.*, 1977). In contrast to water-breathing organisms, air-breathing organisms associated with aquatic environments (*e.g.*, water fowl or aquatic predatory birds) do not have external surfaces that readily facilitate the transfer of lipid-soluble chemicals between internal lipid and external water phases. Consequently, biomagnification in these species is likely to be the determinant factor for the tissue concentration of these contaminants. As noted in Clayton *et al.* (1977), concentrations of contaminants such as PCBs in water-breathing biota from different trophic levels (*e.g.*, zooplankton, herring, and salmon) can be very similar when the values are lipid-normalized. In contrast, concentrations in air-breathing aquatic biota (*e.g.*, birds, seals) can vary widely among species and be considerably higher than in water-breathing biota.

Other organic contaminants, particularly PAHs, also tend to have low water solubilities (solubility decreases with increasing molecular weight) and primarily are found associated with particles and sediments (Pruell and Quinn, 1987). Thus, the principal potential risk from PAHs would be to bottom-dwelling fish and invertebrates, including filter-feeders that ingest PAH-laden particles and associated porewater. However, in contrast to chlorinated compounds such as PCBs, there appears to be a reduced association of PAHs with lipid-rich tissues (Tracey and Hansen, 1996). Because PAH exposures tend to derive primarily from weathered sources (*e.g.*, combusted fossil fuels), these compounds may be more highly particle-bound and hence less bioavailable than would be predicted from their chemical structure (Tracey and Hansen, 1996). In addition, marine vertebrates, (*e.g.*, fish) are very capable of metabolizing PAHs. These factors perhaps explain why this compound class is not bioaccumulated to the same extent as lipophilic organics. The potential effects on humans from exposure to certain PAHs are as carcinogens, particularly at the point of contact, as influenced by the formation of metabolic intermediates.

Metals, such as silver, lead, zinc, arsenic, manganese, mercury, and chromium(+3), all are relatively insoluble in aqueous media and tend to be associated with particles and sediments. Thus, organism exposure pathways are expected to be similar to those noted for the organic contaminants as discussed above. In contrast, nickel, copper, cadmium, and to a lesser extent, chromium(+6), are relatively soluble and characteristically are associated with dissolved phases. Various complex reactions ultimately result in the deposition of these metals in bottom sediments. Subsequent biogeochemical processes (*e.g.*, arsenic methylation) can result in releases of metals from sediments back into the water column. It is also notable that metal speciation in aquatic environments may alter fate and transport; most of the chromium, for example occurs as the less toxic chromium(+3). Physiological requirements and adaptations may also affect the ultimate fate of trace metals. For example, elevated concentrations of copper and zinc are toxic to aquatic biota, but both metals may be accumulated to high concentrations in some species due to physiological adaptations. In general, primary consumers such as bivalves will tend to have higher metals concentrations in tissues than predatory fish (Paine, 1995). However, some metals such as mercury are of special concern because of high potentials for bioconcentration and magnification (*i.e.*, a progressive increase in concentrations from the source of exposure through the trophic levels) within food webs.

4.2. Geotechnical Characterization

This section provides a summary of results for grain size and organic carbon analyses. The sampling locations for surface sediments were discussed in Section 3.6 (Figure 3.6-1 to 3.6-4). A total of 16 surface sediments were analyzed for grain size.

Sediment Grain Size. Figure 4.2-1 shows the classification and percent sand content of surface sediments samples from the Raymark study areas. The results

indicate that the sediments in the study area are quite variable with respect to sand content, ranging from approximately 5% sand at Station E-4 to greater than 98% sand at Station D-3 (Table 4.2-1).silt and clay fractions are also discriminated in this analysis. No station had more than a 2.1% clay composition. Area C sediments were variable, with Station C-1 predominantly composed of sand while Station C-3 was mostly silt. Stations in Areas D and F had varying ratios of sand and silt, with very little clay. Area E Stations had the highest silt content, ranging from 58.7% at Station E-3 to 93.3% at Station E-4.

Organic Carbon. The percent of total organic carbon (TOC) in surface sediments is summarized in Table 4.2-1. The organic carbon content of surface sediment varied widely between 1.3% (C-1) to 28.3% (E-2), likely owing to the highly depositional and vegetated nature of the habitat. TOC in surface sediments was comparatively low at Areas C and D (~< 4%). Area E stations had the highest TOC, ranging from 7% at Station E-3 to 28.3% at E-2. TOC at Area F stations was somewhat lower, ranging from 4.1% to 14.3% (Table 4.2-1).

4.3. Chemical Characterization

This section evaluates the spatial distribution and concentration of contaminants in sediments and biological tissues to describe the possible fate and transport of contaminants from Raymark to receptors of concern. The sections below present data obtained from the analysis for organic and inorganic contaminants in sediments, sediment porewaters and organisms from Raymark. The samples were collected and stored according to established protocols and were analyzed using standard methods. All procedures used in this investigation have been described in the Work Plan for Ecological Risk Characterization of Areas C-F, Raymark Superfund Site, Ferry Creek, Stratford, CT (Appendix F; SAIC, 1999a).

Sediment samples were collected from 16 stations in Areas C-F of the Raymark study site. All station locations are shown in Figures 3.6-1 through 3.6-4. Surficial sediment (approximately 0-15 cm) for risk characterization was collected at these stations, representing recently deposited sediments within the zone of greatest biological activity.

4.3.1. Trace Metal Contaminants

A total of 16 surface sediments were analyzed for nine trace metals. Porewater samples were extracted from each of the 16 surface sediment stations and analyzed for the same nine trace metals. In addition, the surface sediment samples were analyzed for acid volatile sulfides (AVS) and simultaneously extracted metals (SEM). Complete details of analytical methods are provided in the work plan (SAIC, 1999a).

4.3.1.1. Sediments

Trace metals - total digestion. Results of the surface sediments for nine trace metals are presented in Appendix A-1. Non-lithogenic trace metals (*e.g.,* arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver and zinc) are naturally occurring in relatively low background concentrations, but are generally considered to be anthropogenic.

Trace metals in aqueous solution are generally found as positively charged cations. These cations are attracted to negative surface charges on particles (both organic and inorganic), and are precipitated out of solution onto the surface of these particles by a process called adsorption. Smaller particles tend to coagulate into larger particles and sink to the sediment column (*i.e.*, clay and fine silt). Small particles, generally less than 25 μm in size, have a higher density of negative surface charges than coarser sand particles (*i.e.*, greater than or equal to 62 μm). For this reason, muds generally contain significantly higher concentrations of adsorbed trace metals than sands when both sizes are exposed to similar environmental concentrations.

Concentrations of trace metals (copper, lead, mercury and zinc) in surface sediments of the Raymark Study area compared to NOAA ER-L and ER-M guidelines (Long *et al.*, 1995) are shown in Figure 4.3-1. Elevated levels of anthropogenic metals are observed at several Raymark stations. ER-M values were exceeded for copper at Stations C-2, C-3, E-1, F-2, and the reference. ER-M values were exceeded for lead at Station E-1, F-2, and F-3 and for mercury at C-3, E-1 and the reference, whereas ER-L values were exceeded for multiple metals at multiple stations (Figure 4.3-1). These figures also indicate that the stations with the highest concentrations, with respect to NOAA criteria, are C-3, E-1, F-2, F-3, and the reference.

Simultaneously Extracted Metals (SEM) and Acid Volatile Sulfide (AVS) study of surface sediments. Concentrations of SEM and AVS were measured as an indicator of potential adverse exposure to divalent metals. Results for individual metals and AVS for each station are shown in Figure 4.3-2. For SEM metals, it is apparent that zinc is the primary metal contributing to the Total SEM concentration with copper, nickel, and cadmium contributing minor amounts. In contrast, Pb is typically a minor component of the Total SEM value. Figure 4.3-2 also shows station-specific AVS concentrations. Three stations (C-3, D-1, and E-3) have negligible AVS amounts (< 0.1 μMole/g dry weight), while nine stations have very large quantities (> 10 μMole/g dry weight). This variation in total AVS is expected to have substantial influence on potential adverse exposure to metals as discussed below.

The concentration of SEM relative to AVS (SEM-AVS) is the primary criterion for determining the potential toxicity of divalent metals in the sediment matrix (DiToro, *et al.,* 1991). However, because sulfides are easily oxidized to sulfates which do not bind metals, and because the bacterial activity which produces sulfides may be seasonal, interpretation of metal bioavailability for this ERA also considers the possible scenario

in which AVS concentrations may be minimal. Thus, the interpretation of SEM bioavailability presented in Table 4.3-1 includes the consideration of SEM bioavailability at an AVS concentration equal to zero (SEM) and SEM in excess of AVS (SEM-AVS).

Data in total SEM assuming AVS = 0 indicate potentially high SEM exposure at for Selby Pond Station F-3 (> 20 μMole/g dry weight), and intermediate exposure at Stations F-1 and F-2 as well as Area E Stations E-1 and E-2 (> 10 μMole/g dry weight). Conditions at Stations C-2, D-3, E-3, and E-4 suggest low exposure since SEM concentrations are only slightly above 5 μMole/g dry weight. Baseline exposure was found for remainder of the study area, including most of the Area D stations.

Data on SEM-AVS indicate that generally high AVS throughout the study area acts as an effective buffer for potential divalent metals exposure. SEM in excess of AVS was observed only at five stations, of which only two suggested intermediate exposure (SEM-AVS > 5 μMole/g dry weight). The three other stations (C-3, D-1, and E-2) had low excess SEM, and the remaining stations had none (baseline exposure).

The overall exposure ranking for SEM:AVS measurements is provided in Table 4.3-1, and considers the weight of evidence presented for SEM only and SEM-AVS results. Overall, it is concluded that six stations (D-3, E-1, E-2, E-3, F-1, and F-2) pose low exposure conditions to SEM metals, and one station (F-3), represents an intermediate exposure condition. Baseline exposure conditions exist at the remaining stations including the reference location.

4.3.1.2. Porewater

Porewater samples from each of the 16 surface sediment samples were analyzed for metal contaminants. Analytical measurements are summarized in Appendix A-2. These results were combined with previously measured concentrations at the reference location GM-08 (see SAIC, 1998).

Arsenic concentrations in the porewater samples ranged between < LQD (Limit of Quantitative Detection) to 42.9 mg/kg for Station C-1. Cadmium concentrations ranged between < LQD and 0.4 mg/kg at Station D-3. Chromium ranged between < LDQ and 13.7 mg/kg at E-2. Copper ranged between < LDQ and 55.00 mg/kg at the reference station. Lead concentrations ranged between < LDQ and 34.6 mg/kg at E-2. Nickel concentrations ranged between < LDQ and 32.00 mg/kg at the reference station. Silver was below the LDQ for all stations sampled and was estimated to be 0.001 mg/kg at the reference station. Zinc concentrations ranged between < LDQ and 420 mg/kg for the reference station. Mercury was not measured in the porewater (see Appendix E-1).

Copper showed exceedence relative to WQC-Saltwater Acute (SA) benchmarks for five stations (D-3, E-1, E-2, E-3, and F-2), in the Raymark study area as well as the reference station (see Figure 4.3-3). For lead, only Station E-2 had a concentration

which exceeded the WQC-SC benchmark. Three stations exceeded this benchmark for nickel (E-3, E-4, and the reference). Only the reference station exceeded the WQC-SC and WQC-SA benchmarks for zinc (Figure 4.3-3).

4.3.1.3. Tissue Residues (metals)

The metals measured in the tissue samples were the same as those reported for the sediment samples (*i.e.*, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc). The concentrations of four representative inorganic contaminants in ribbed mussels from the Raymark study area are shown in Figure 4.3-4. Ribbed mussels were not sampled from the reference station. Raw data are reported in Appendix Table A-3. All of the metals concentrations in mussels were comparable over the study area, exhibiting about two-fold variation.

4.3.2. Organic Contaminants

A total of 16 surface sediments samples were analyzed for PCBs, PAHs, pesticides (OCPs), and dioxins. All sediment values are reported on a dry weight basis (ng/g) and porewater values are reported on a volumetric (ng/L) basis. Complete sampling and analytical details have been reported by SAIC (1999a).

4.3.2.1. Sediments

Figure 4.3-5 presents the concentrations of organic contaminants (PAHs, PCBs, DDTs and dioxins) in Raymark surface sediments. The actual contaminant concentrations measured in these sediments are shown in Appendix A-1. For the PAHs, the concentrations at 12 stations exceeded the ER-L value of 4022 ng/g and two of these stations also exceeded the ER-M value of 44,792 ng/g. The highest value was observed at Station F-3 (127,320 ng/g). The reference station also exceeded the ER-L value.

Concentrations of the PCBs were greater than the ER-L value of 22.7 ng/g at all stations in the Raymark study areas (Figure 4.3-5). Nine stations also exceeded the ER-M value of 180 ng/g (C-2, D-4, D-5, E-1, E-2, E-4, F-1, F-2, and F-3). As in the case of the PAHs, the reference station exceeded the ER-L value and had a elevated level of PCBs.

The major OCPs observed in the study were the DDTs and the sum of five of these compounds is shown as Sum DDT in Figure 4.3-5. Thirteen of the stations exceeded the ER-L value of 1.89 ng/g, and five were greater than the ER-M concentration of 27 ng/g. Highest sum DDT values were found at Stations F-2 and F-3; measured concentrations were 126.7 ng/g and 226.2 ng/g.

Dioxin data from sediments collected in the Raymark study area are presented in Figure 4.3-5. Most stations were below the lower threshold value of 60 pg/g for fish

(EPA, 1993d). Only 2 stations were above this value, and these stations were also above the high threshold value (100 pg/g).

4.3.2.2. Porewater

Porewater in sediment samples were not analyzed for organic contaminants as had been done for metals. The large porewater volumes required to achieve useful detection limits (*e.g.,* 1 ng/L) were deemed impractical for this study. Instead, predictions of porewater concentrations using the equilibrium partitioning (EqP) model of DiToro *et al.*, (1991) were performed and will be discussed in Section 6.1.3 to complete the risk assessment of porewater organics.

4.3.2.3. Tissue Residues

Figure 4.3-6 shows concentrations of organics in ribbed mussels collected from seven stations in the study area; analytical data are reported in Appendix A-1. For Total PAHs, residue concentrations exhibited a small range of variation (680 - 1000 ng/g dry wt) as did Total PCBs (106-243 ng/g dry wt). For DDT, three stations had detected concentrations (C-3, D-1 and D-2) in the 6-24 ng/g dy wt range.

4.4 Uncertainty

Contaminant sources, distribution and concentration in Raymark have been characterized based on data from present and previous studies. However, the exposure pathways as reflected by the first through fourth tier models (Section 3.5) are necessarily conceptual and cannot account for all the complexities of a natural ecosystem, including proximal and distal sources, as well as potential receptors. These uncertainties also are driven by incomplete knowledge of the chemical behavior of the CoCs, even though considerable information is available on solubility, partitioning, and toxicity for several analytes. Nonetheless, existing information on the chemical contaminants and a reasonably thorough understanding of the ecosystem have allowed sufficient and relevant data to be targeted, collected, and interpreted for the risk assessment.

Spatial variability. Fate and transport evaluations for the exposure assessment focused on spatial (horizontal) patterns as well as data comparability among the matrices sampled (sediment and tissue). The placement of sampling stations was largely based on providing complete coverage of the various areas of Raymark. Station placement was guided additionally by results from prior studies; however, visual coverage was a principal method applied. The uncertainty associated with any sampling station is whether it is truly representative of the habitat and impact/reference zone being evaluated.

Collection of station replicates is one method that allows assessment of within-

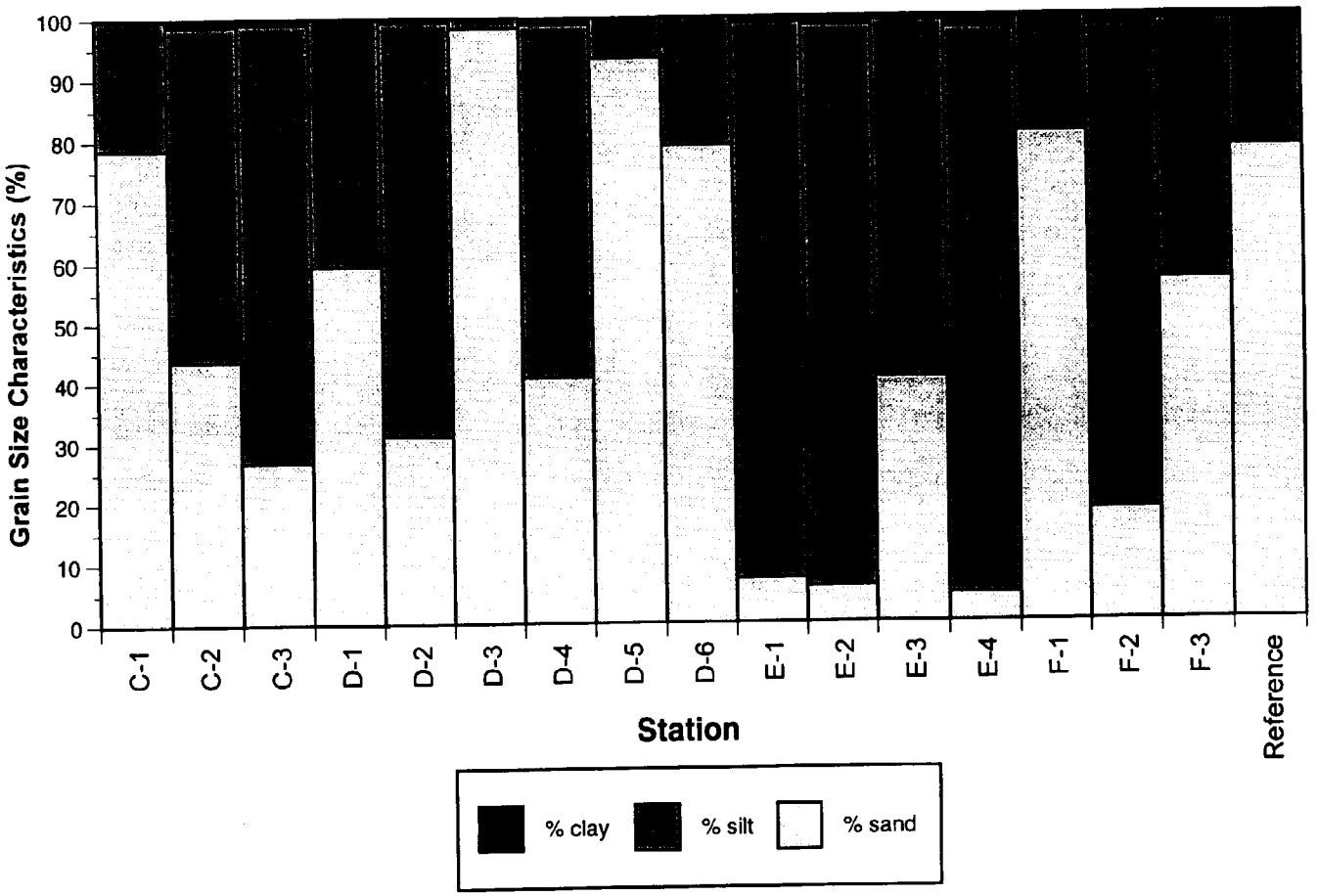
station variability (*i.e.,* the representativeness of a sample). Although only single samples were generally collected per station for this study, agreement among field duplicate measurements suggests that small scale spatial variation was not problematic. Hence, comparison of the data variability among stations is the primary method used to assess adequacy and representativeness of the sampling positions.

There are uncertainties of extrapolations (and assumptions) from point measurements to broader spatial areas, but geotechnical studies have helped fill the "gap", by providing quantitative information on spatial scales of variability in sediment lithologic properties (*e.g.,* TOC, grain size, erodability) which strongly influence CoC distribution. Additional quantitative approaches using Geographic Information Systems (GIS) technology, including the development of concentration contours have been recently reported (Clifford *et al.*, 1995); this approach appears to provide an effective, unbiased method for estimating spatial extent of exposure, thereby minimizing interpretive uncertainty and maximizing data usage. Application of these techniques may be useful when sediment remediation strategies are investigated. QA/QC and data validation for sample inventory and analysis are presented in Appendix C.

Temporal variability. Another area of uncertainty for the exposure assessment is the temporal comparability of data. The general study design assumes that there have not been substantial changes in environmental conditions and chemical contaminant concentrations at individual sampling sites, as representative of particular habitat and sampling zones. In practice, however, interannual and seasonal variations occur in every environment, thereby changing to some degree the conditions that influence contaminant sources, exposure pathways, and receptors. Nonetheless, the assumption that temporal changes in sediment chemistry are not significant appears correct.

The exposure point estimates are based on representative chemical analytes that, due to practicality, are a subset of the total possible compounds that could be analyzed. However, the analytes have been carefully selected as a result of extensive screening and analyses during the present and previous studies and are considered to be appropriately conservative and representative of source contaminants. Calculations of SEM for use in comparisons with AVS values utilize sediment data on copper, zinc, lead, nickel, and cadmium. Each of these metals is commonly accepted as reacting in the presence of sulfides in a manner which fulfills the assumptions of the AVS paradigm. However, there is new evidence suggesting the appropriateness of including silver in the calculations. This is because silver can react in a manner that is similar to a divalent metal. For this assessment, silver has not been included in the SEM calculation, since this analyte was not identified as a CoC.

Figure 4.2-1. Grain size characteristics in surface samples from the Raymark study area.



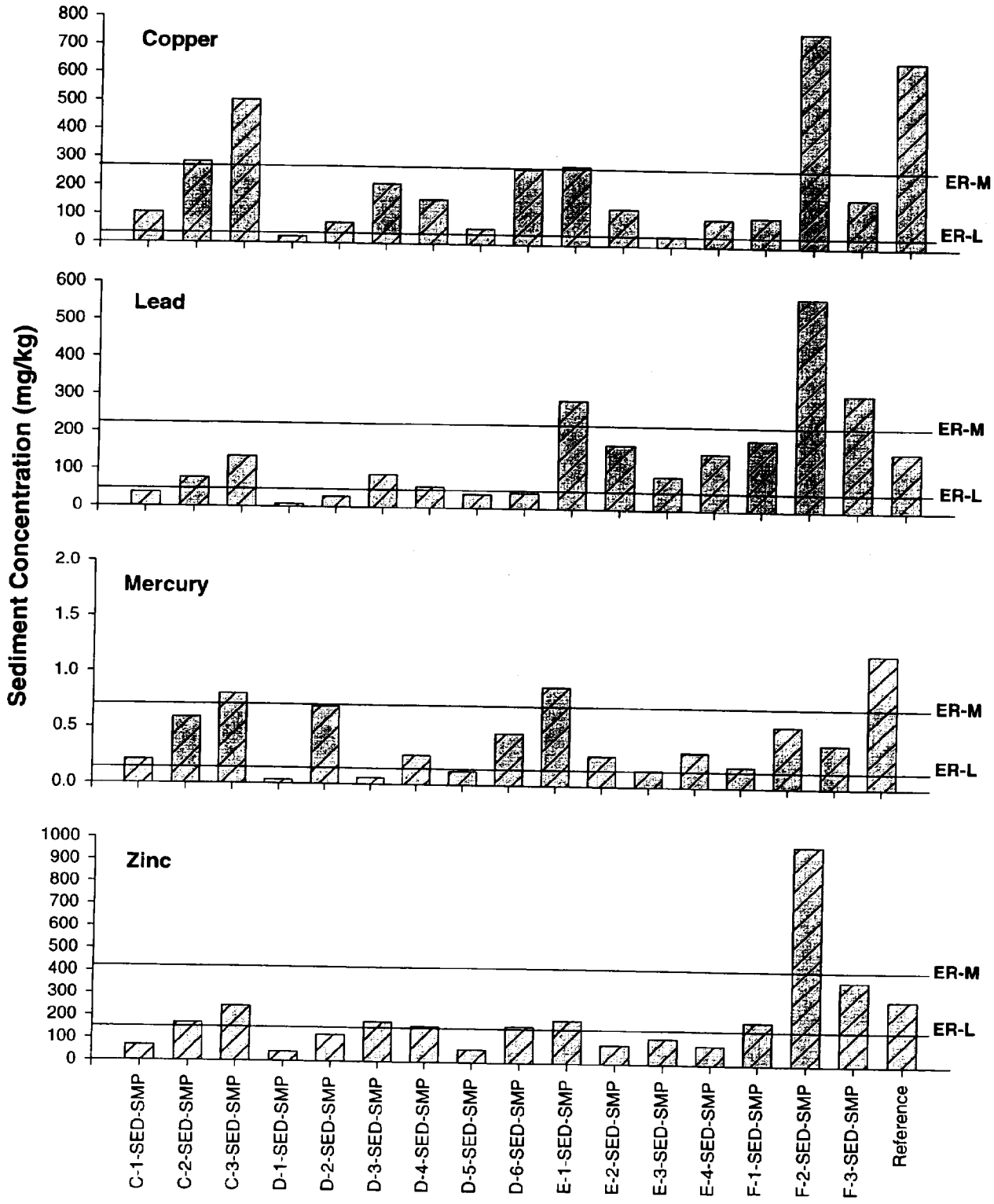


Figure 4.3-1. Concentration (mg/kg) of metals in sediments from the Raymark study area.

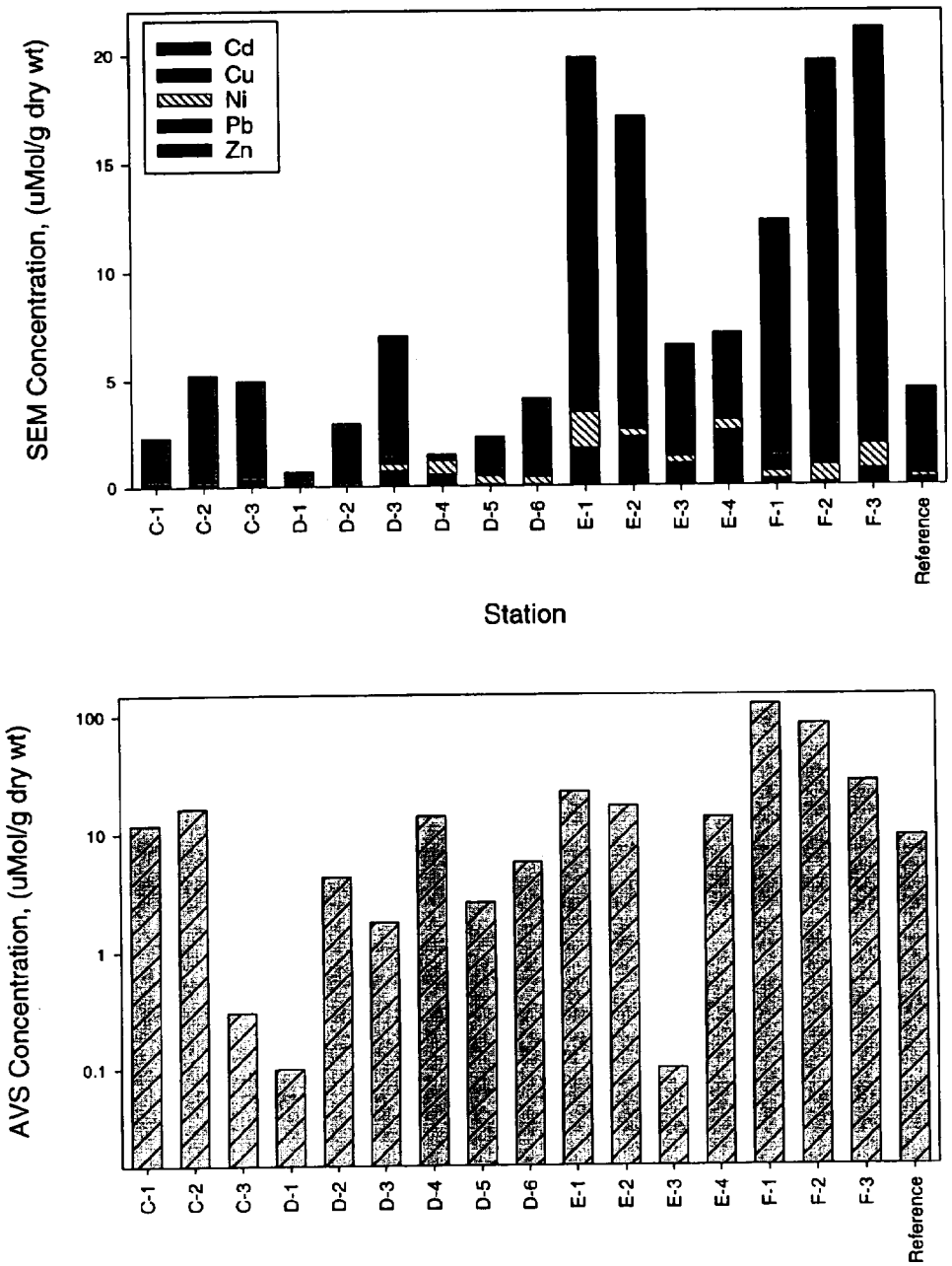


Figure 4.3-2. SEM and AVS concentrations (μMol/g dry wt) of divalent metals in whole sediments collected from the Raymark study area.

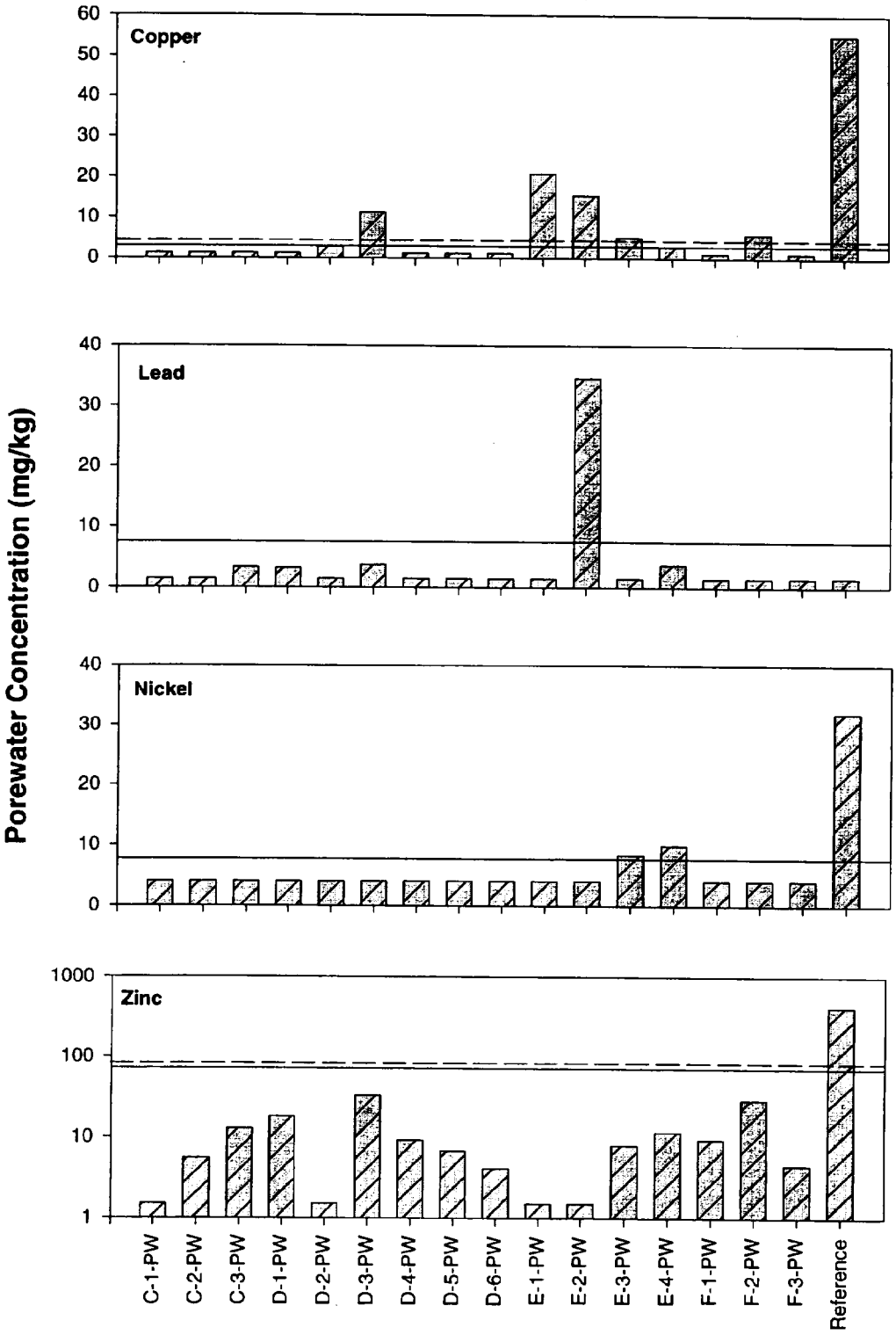


Figure 4.3-3. Concentration (mg/kg) of metals in porewater samples from the Raymark study area. Solid lines designate the Saltwater Chronic Values and dotted lines designate the Saltwater Acute Values.

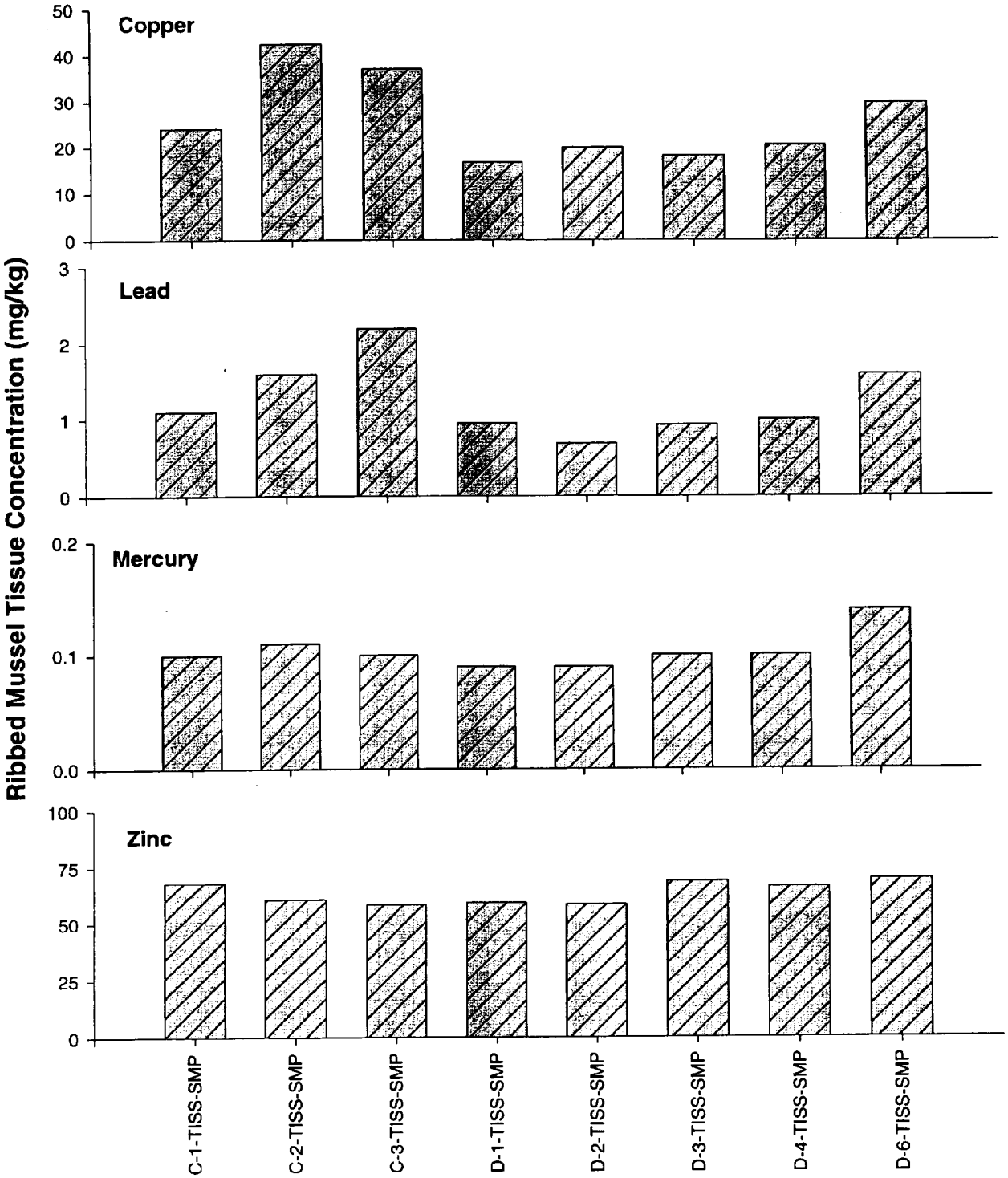


Figure 4.3-4. Concentration (mg/kg) of metals in ribbed mussels from the Raymark study area.

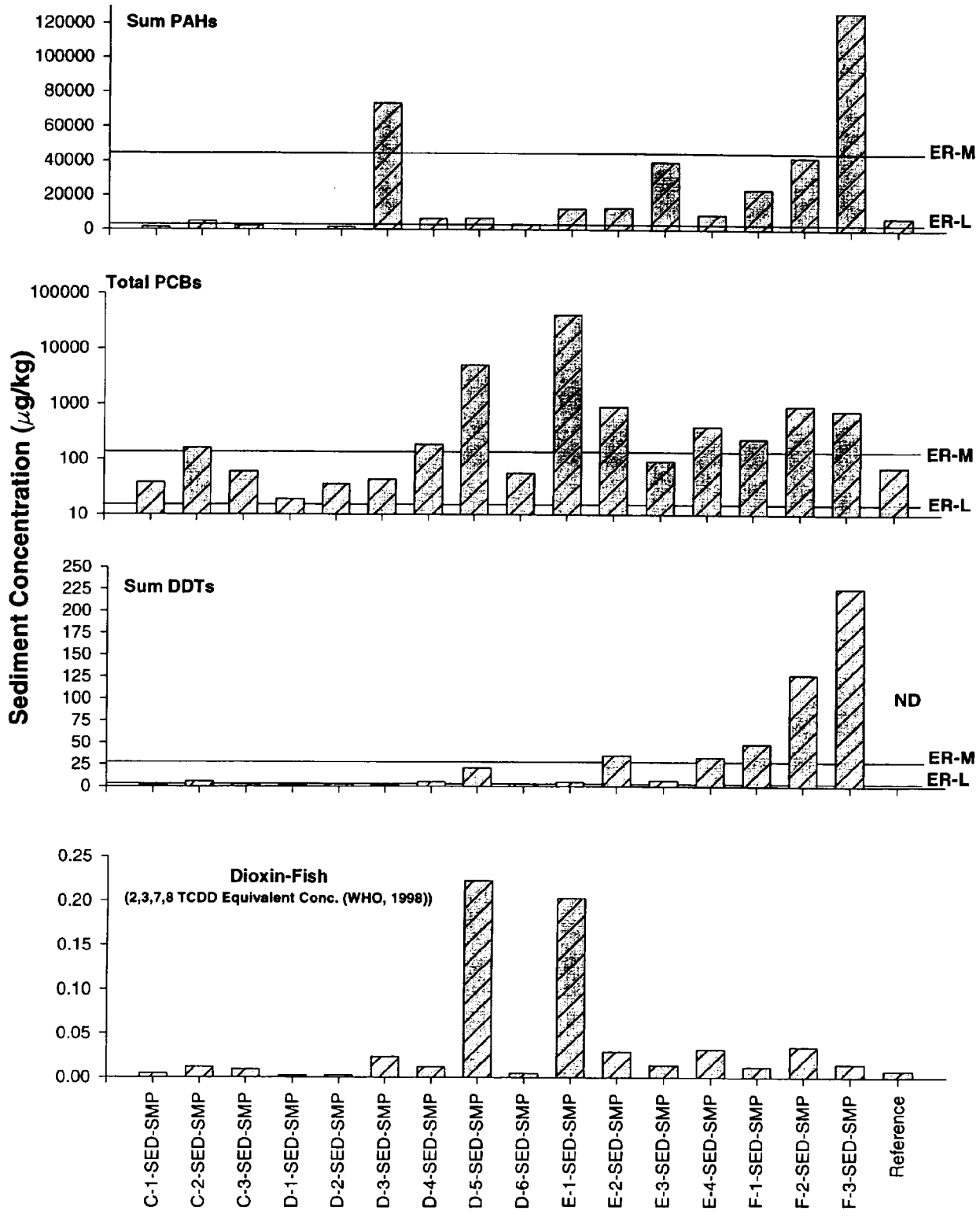


Figure 4.3-5. Concentration (µg/kg) of organics in sediment from the Raymark study area. (ND=No Data)

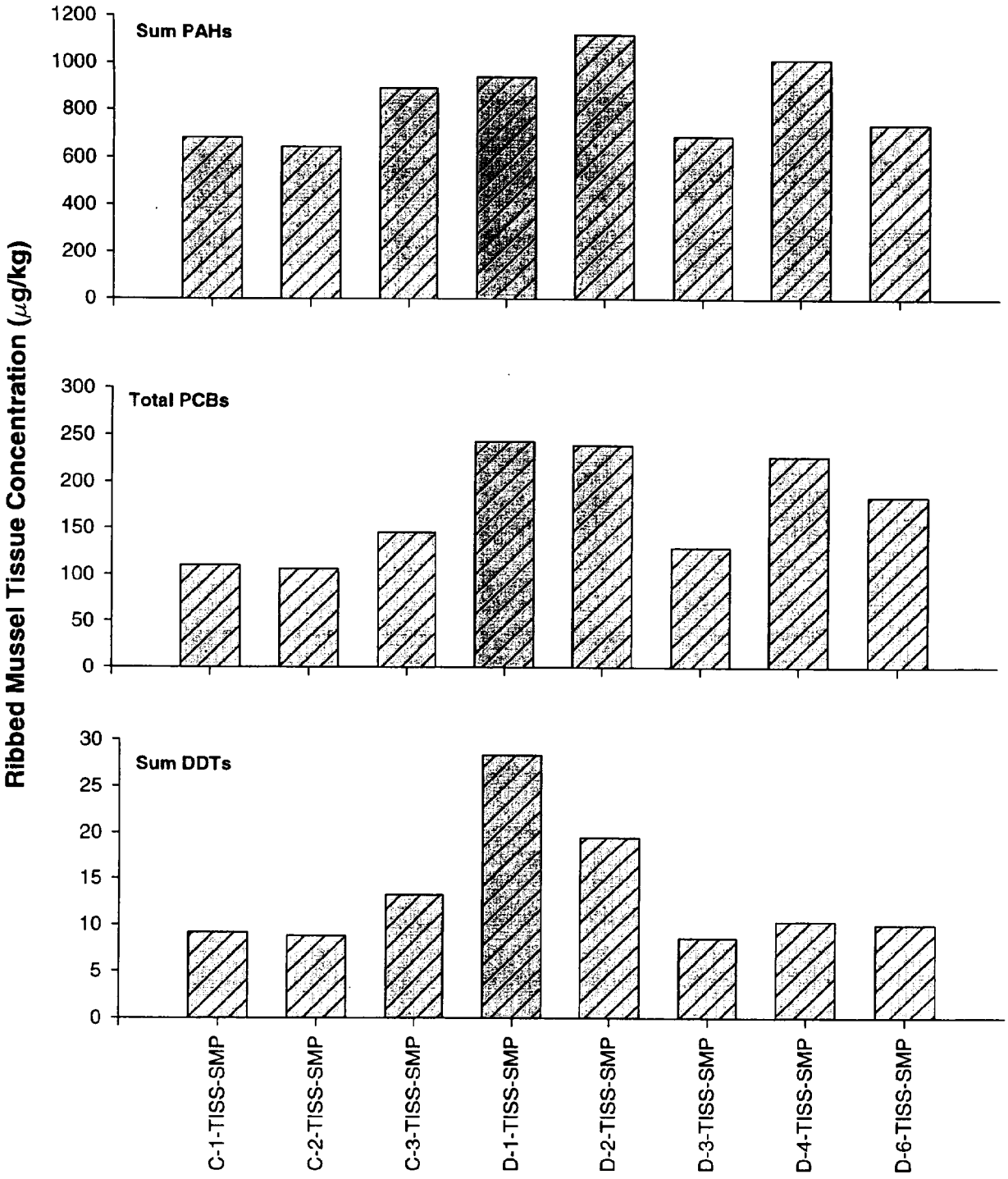


Figure 4.3-6. Concentration (µg/kg) of organics in ribbed mussels from the Raymark study area.

Table 4.2-1. Total Organic Carbon Content (TOC) and Grain Size of surface sediments collected from the Raymark study area.

Station	Surface TOC (%)				%SILT	
		% SAND	% SILT	%CLAY	63-15.6u	<15.6u
C-1	1.30	78.60	21.10	0.30	14.00	7.40
C-2	3.10	43.70	55.10	1.20	34.10	22.10
C-3	4.10	26.90	72.10	1.00	43.50	29.60
D-1	1.70	59.40	40.40	0.20	31.30	9.30
D-2	3.40	31.20	68.10	0.70	38.60	30.30
D-3	2.00	98.30	1.70	0.00	1.00	0.70
D-4	3.40	40.70	58.10	1.10	30.40	28.90
D-5	1.40	93.20	6.70	0.00	4.20	2.60
D-6	1.50	79.00	20.80	0.20	13.70	7.40
E-1	9.30	7.30	91.60	1.10	41.50	51.20
E-2	28.30	5.90	92.50	1.70	36.20	57.90
E-3	7.00	40.50	58.70	0.80	32.80	26.70
E-4	22.00	4.60	93.30	2.10	37.30	58.10
F-1	4.10	80.90	18.70	0.40	8.40	10.80
F-2	14.30	18.40	79.60	2.00	40.20	41.40
F-3	13.90	56.70	42.20	1.10	19.70	23.70
Reference	5.86	78.33	21.67	0.00	8.18	13.49

Table 4.3-1. Results of Simultaneously Extractable Metal (SEM) and Acid Volatile Sulfide (AVS) measurements in sediments and qualitative evaluation of divalent metal bioavailability for the Raymark Phase III Ecological Risk Assessment Investigation.

Station	AVS[1]	SEM		SEM-AVS		Exposure Ranking[3]
	(µMole/g dry)	(µMole/g dry)	FLAG[2]	(µMole/g dry)	FLAG[2]	
C-1	11.81	2.32	-	-9.5	-	-
C-2	16.22	5.23	+	-11.0	-	-
C-3	0.30	4.94	-	4.6	+	-
D-1	0.10	0.68	-	0.6	+	-
D-2	4.29	2.93	-	-1.4	-	-
D-3	1.79	7.02	+	5.2	++	+
D-4	13.95	1.48	-	-12.5	-	-
D-5	2.62	2.30	-	-0.3	-	-
D-6	5.68	4.11	-	-1.6	-	-
E-1	22.22	19.84	++	-2.4	-	+
E-2	16.77	17.12	++	0.4	+	+
E-3	0.10	6.58	+	6.5	++	+
E-4	13.38	7.14	+	-6.2	-	-
F-1	124	12.30	++	-112.1	-	+
F-2	83.45	19.72	++	-63.7	-	+
F-3	27.01	21.23	+++	-5.8	-	++
Reference	9.40	4.53	-	-4.9	-	-

1 - Mean of two replicates per station.
2 - Flag Codes: SEM Conc. < 5 µmol/g; SEM-AVS < 0 µmol/g = "-".
SEM Conc. ≥ 5 µmol/g; SEM-AVS ≥ 0 µmol/g = "+".
SEM Conc. ≥ 10 µmol/g; SEM-AVS ≥ 5 µmol/g = "++".
SEM Conc. ≥ 20 µmol/g; SEM-AVS ≥ 10 µmol/g = "+++".
3 - Exposure Ranking:
Baseline ("-") - Low (+) exposure observed for only one indicator or baseline (-) exposure for both indicators;
Low ("+") - Low (+) exposure observed for both indicators or intermediate (++) exposure for one indicator;
Intermediate ("++") - exposure observed for both indicators or high (+++) exposure for one indicator; and
High ("+++") - exposure observed in both indicators.

5.0 Ecological Effects
(pages 86-120)
is available
in a separate file (size: 2.1 MB).

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6.0 Risk Characterization,
7.0 Summary & Conclusions &
8.0 References
(pages 121-213)
are available
in a separate file (size: 4.2 MB).

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Appendix A: Analytical Chemistry Results,
Appendix B: Effects Data &
Appendix C: QA/QC and Data Validation
(pages 214-313)
are available
in a separate file (size: 4.7 MB).

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Appendix D: Ecological Risk Calculations,
Appendix E-1: Workplan for Ecological Risk Characterization &
Appendix E-2: Sample Log Sheets for Areas C-F
(pages 314-433)
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in a separate file (size: 4.8 MB).

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